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AND OTHERS

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TECHNOLOGY and CULTURE

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As this issue of *Technology and Culture* goes to press, word reaches us of the death of Dr. David B. Steinman, President of the Society for the History of Technology. One of the world's outstanding bridge builders, Dr. Steinman combined technical genius with aesthetic insight. He was deeply concerned with the humanistic elements in engineering, as is evidenced by his own writings, which included poetry and biography as well as technical and scientific papers, and by the leading role which he played in our organization. His death is a great loss to our Society as well as to the entire world of scholarship.

The next issue of *Technology and Culture* will contain "An Appreciation of David B. Steinman" by Dr. S. R. Watson, an authority on civil engineering and a writing collaborator of Dr. Steinman.

DR. CHARLES SINGER

(1876-1960)

Principal Editor of *A History of Technology*

Introductory

CHARLES SINGER AND "A HISTORY OF TECHNOLOGY"

MELVIN KRANZBERG*

THIS ISSUE OF *Technology and Culture* is devoted wholly to critical analyses of the five-volume *A History of Technology*, edited by Charles Singer, E. J. Holmyard, A. R. Hall, and Trevor I. Williams. Dr. Singer's introductory article to this review issue, telling how and why *A History of Technology* came into being, was the last article to issue from his pen. In mid-May we received a letter from Dr. Singer in which he explained that he had his introductory article half written, but that he had been delayed by illness and was starting work on it again. A month later word reached us of the death of Dr. Singer at his home in Cornwall, England in his eighty-fourth year; in the interval he had finished the manuscript which appears in this issue.

Charles Singer's entire life was dedicated to scholarship, and he achieved outstanding recognition as a pioneer in three related fields: the history of medicine, the history of science, and the history of technology. Starting his career as a physician, his historical bent soon manifested itself, and there began that remarkable series of publications in the history of biology and of medicine which established Dr. Singer as a scholar of the first rank. The value of his contribution can be judged by the fact that many of his books written in the 1920's have been reprinted in the 1950's and still remain the standard works in their fields. One reason for the new editions thirty or more years after original publication is the growing interest in the history of science, a new discipline in which Dr. Singer pioneered along with George Sarton, his close and good friend. It is not surprising that Dr. Singer's work should have been recognized by an honorary Doctorate of Science and an Honorary Doctorate of Literature from Oxford, by his being made an Honorary Fellow of Magdalen College, Oxford, by his election to the presidency of the British Society for the History of Science and of the International Academy for the History of Science (and subsequently of the International Union for the History of Science),

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and by numerous other honors, including Corresponding Membership in the Society for the History of Technology.

Dr. Singer had great personal charm as well as vast erudition. A quiet, soft-spoken man, a gentle warmth radiated from him, and a twinkle in his eye betrayed his keen sense of humor. He was always ready to help other scholars in their work, and his home on the Cornish Riviera, whence he had retired, became a place of pilgrimage for distinguished historians and scientists who sought the benefit of his advice and the stimulation of his lively mind. They were attracted there also by Mrs. Singer. A famed historian of science in her own right, Dorothea Waley Singer shared her husband's interests and worked closely with him.

In his conversation and his correspondence as well as in his published works, Dr. Singer revealed himself as that rarest of individuals–the truly well-rounded man. His acute mind, his perceptive analysis of men and events, his ability to synthesize a multitude of details and to express his thoughts in beautifully simple language–all these were traits of the man as well as of the scholar. Above all, he was a man of breadth of intellect and of humane interests.

This is why he was able, after having established himself as one of the world's foremost scholars in the history of science and of medicine, to pioneer in a new field: the history of technology. Although he had published some early reflections on the relations between history and technology (*Technology and History*, 1921), he was already a Professor Emeritus of the University of London when he entered into a serious study of the history of technology. It is not surprising that a man of such great intellectual powers and humane spirit should have been attracted to the study of those technological developments which accompanied the birth and growth of civilization. And it is a mark of his greatness that he was the obvious choice to edit the monumental five-volume work which provides the reference point for future scholarship in this new discipline.

Although Dr. Singer's writings in the history of medicine and of science are more than enough to give him long-lasting scholarly fame, his work in conceiving *A History of Technology* may well prove his most enduring monument. Individual monographs can be forgotten or superseded, but great cooperative works of this type and on this scale, despite weaknesses and shortcomings, stand for many years to come as foundation stones. This is particularly the case in a new discipline, such as the history of technology, where the field had first to be delineated and where vast amounts of material had to be brought together so as to provide the basis for future work. The memory of Dr. Singer's warm and kindly spirit lives on in the hearts of his friends, who are legion. The scholarly work of Charles Singer will live for many generations to come in the minds of scholars everywhere as they

turn again and again to his writings for information and inspiration. All of us are in his debt.

* * * * *

A History of Technology occupies so important a place in the public mind as the "definitive" work on technology—and it is so fundamental to the scholar in this new and burgeoning field—that it is not surprising that it was deemed worthy of a full-scale review occupying an entire issue of *Technology and Culture*. If scholars from many different fields are to approach the study of technological development with some understanding of the elements involved therein, it is essential that some evaluation be made of this encyclopedic work, that its shortcomings as well as its contributions be pointed out, and that its place in the world of scholarship be defined.

Prepared and published with the aid of a generous subsidy from Imperial Chemical Industries, Ltd., *A History of Technology* was edited by Dr. Singer together with E. J. Holmyard, A. R. Hall, and Trevor I. Williams. It was published in five volumes by the Oxford University Press as follows:

Volume I—From Early Times to the Fall of the Ancient Empires (1955)

Volume II—The Mediterranean Civilizations and the Middle Ages (1956)

Volume III—From the Renaissance to the Industrial Revolution (1957)

Volume IV—The Industrial Revolution c. 1750 to c. 1850 (1958)

Volume V—The Late Nineteenth Century c. 1850 to c. 1900 (1958).

In an effort to give a full presentation of the significance and contributions of *A History of Technology*, the editors of *Technology and Culture* asked A. R. Hall, one of Dr. Singer's co-editors, to tell of some of the editorial problems encountered in putting together a massive collaborative work in a new field. Dr. Hall's discussion of the rationale behind the entire project is followed by reviews of a general nature by important scholars in this field. Then follows a series of reviews by experts in the specific fields of technology represented in the *History*. The reader may thus hope to gain not only a general picture of the merits and defects of *A History of Technology*, but also detailed critiques of the treatment of specialized fields within the volumes.

The Singer volumes occupy so important a place in the history of technology that they have become the criterion by which all other attempts to deal with this subject are measured. Study of the history of technology is by no means confined to the English-speaking countries, just as technology itself is by no means the monopoly of any certain nation or race but represents a common heritage of all mankind from its very beginnings. Thus the final section of this issue

contains comparisons of the Singer volumes with similar large-scale histories of technology now being published or soon to be published in languages other than English.

It will be noted by the reader that many of the reviews of *A History of Technology* are highly critical of that work, either in whole or in part. Dr. Singer himself was well aware of the shortcomings of those volumes; he regarded them not so much as a finished product, representing the "final word" in the history of technology, but rather as a beginning attempt which would stimulate and encourage further research and necessary scholarship. "The important thing about *A History of Technology*," Dr. Singer once insisted to this writer, "is that it is there." It marked a necessary step in scholarly work which must be accomplished before further strides could be taken. As far as the criticisms, sometimes rather harsh, of *A History of Technology* expressed in this issue of *Technology and Culture*, I think Dr. Singer would have enjoyed rather than resented them. He would have been pleased to see criticism and controversy evoked by this pioneer attempt to provide "a longer perspective of the ways in which the immensely complex technical knowledge of our civilization has come into being." Yes, I am quite sure that he would have relished the criticisms, the harsher the better. As a man of rigorous intellectual honesty and great humility, he would not have had it any other way.

HOW "A HISTORY OF TECHNOLOGY" CAME INTO BEING

CHARLES SINGER

A History of Technology is a work in five large volumes published by the Clarendon Press at Oxford between 1954 and 1958. It is the only major English work that attempts to cover the whole area of the subject from the earliest times till about the end of the nineteenth century. It had ultimately four editors. Of these I was the senior. That is doubtless the reason why the editor of this journal asked me to give some account of the inception of the undertaking. Since I made the first draft of the scheme I trust that the reader will forgive me for telling the story in an autobiographical vein. Nevertheless I would like to emphasize that each of my colleagues contributed quite as much, probably more, than I to the general editorial work.

In the late spring of 1950, I had attended a very successful conference on the history of technology in Holland. I did this in company with my old friend, the late Dr. H. W. Dickinson. He was, from its incep-

tion and to the end of his life, the greatest moving force of the Newcomen Society, being one of its founders in 1920 and the editor of its *Transactions* for many years. I too was an original member of the Society and, though never active in it, I very soon learned to have great respect for Dickinson's attainments and affection for his character. Indeed, I became deeply attached to him.

Dickinson was a man of remarkable erudition and scrupulous scholarship. In temper he was very cheerful and sociable, but modest to a degree and quite unambitious. As a well-trained civil engineer with wide scientific tastes, he was for many years happy and contented as a "Keeper," and occasionally Deputy Director, at the Science Museum in London. His best work is to be seen in his several published volumes and in the *Transactions* of the Newcomen Society itself. During his very long editorship every line of that publication was carefully considered by him and, at need, verified. That was one reason for the very high standard of its volumes.

I came to know Dickinson intimately from 1931. At the Third International Congress of the History of Science and Technology—held in London in that year—he was honorary secretary and I president, though truly the positions should have been reversed, but for his retiring and modest temperament.

From about 1927 I had been trying to summarize the history of sciences into an elementary form. The attempt had often been made. Not the least effective had been that of a hundred years earlier by the distinguished Master of Trinity College, Cambridge, William Whewell. After some years of effort, I had concluded that the task was impossible for one man. The non-scientific public—and often the scientific public—demands the latest advances in science, and the latest are not only the most uncertain but the most difficult to expound. I came gradually to realize that the ever-changing branches of the great delta of discovery on which modern research debouches must be distinguished from the more ancient and relatively constant stream of positive knowledge. To that stream our attitude changes relatively little or, at least, relatively slowly.

But where does the stream end and the delta begin? The answer surely is: About the beginning of the independent intellectual working life of the particular writer. This, for me, is about 1900, and this happens to be an exceptionally fortunate date from the point of view of the historian of science. It marks a real period. Thus it corresponds roughly with the enunciation of the quantum theory, of the discovery of electrons, of the general theory of relativity, of the view of "island universes," of the resurrection of Mendelism, of the elucidation of the chromosomal meaning of sex and of the theory of the genes, with the rise of biochemistry and of a realistic view of the chemical make-up of living matter. By such theories and problems as these the whole face of science was changed. The record of science from about 1900

must be written in quite a different way and perhaps in a different spirit from that in which its previous history should be attacked.

In frequent discussion with Dickinson, I learned that he had reached similar conclusions for technology. This we both recognized must ultimately have a separate history, more closely related to the affairs of men than the history of science. Dickinson, however, was less sanguine than I as to the possibility of making world-technology the topic of any continuous study. There is good hope that this journal will prove him to have been wrong in this respect.

I am not a technologist by training but, after a long period of study of the history of science, I fell into thinking on the study of technology by a happy accident. When the war began in 1939, University College, London, where I taught, was evacuated and as many departments as possible, including my own, were suspended. I was then 62. I offered my services as a science teacher to King's School, Canterbury, which had been moved to Cornwall, close to my home, and I continued this work till the war ended.

In November 1943, I was approached by my friend Mr. Derek Spence, then managing director of one of the oldest firms for the making of heavy chemicals in Britain, Peter Spence & Sons Ltd., to write something in the way of the technological history of alum to commemorate the centenary of his firm in 1946. The scheme suited me since the technology and chemistry of it was comparatively simple. Nevertheless we soon realized that his scheme would not be practicable at the set date, even on the most limited scale. Many libraries were closed for the duration of the war, all were very short of staff. Paper was strictly rationed and remained so till long after the war ended. Even then there was a great shortage of printers and specially of blockmakers, many of whose works had been wrecked. Nothing adequate could even be begun in the way of printing until 1946.

However I secured the help of Dr. Elsbeth Jaffé, a most learned lady in classical history, who worked partly at Cambridge and partly in my own library in Cornwall. Between us we got ready a volume, *The Earliest Chemical Industry, An Essay in the Historical Relations of Economics & Technology illustrated by the Alum Trade*. Alum was a substance in the making of which there had been, for centuries, international competition often involving high policy. The firm of Peter Spence & Son Ltd., had risen largely by the invention, by Mr. Derek Spence's great-grandfather, of a method of making alum on an industrial scale from certain waste products. With great difficulty we assembled our text and suitable illustrations. Even with the end of the war in 1945, shortages continued for years. So far as book production was concerned, these were especially severe for paper. Arrangements were presently made for the beautiful production of the book by the Folio Society. By 1947-8 the blockmakers were beginning to

be at work again, and the book was produced before 1948 was over. It was well received.

This volume drew the attention of certain of the directors of Imperial Chemical Industries, Ltd. (I. C. I.). On my return from the trip with Dickinson to Holland in 1950 I was invited to call on a small group of them to discuss the possibility of the production of a comparable work. I suggested that a history of technology in a series of volumes would be the most appropriate. Several of those present suspected that such a work must already be in existence but I assured them that, though I had worked on the subject for some years, I had found none. It was suggested that we meet again and that I draw up a scheme for such a work, and meantime I was able to reassure them that no such work existed. The matter was placed in the hands of a small committee of directors consisting of Dr. C. J. T. Cronshaw, the late Sir Wallace Akers, and Mr. (now Sir) Walter Warboys.

The scheme that I then drew up is here before the reader in its original form. It was accepted by the committee, and I suggested that my old friend, the late Dr. E. J. Holmyard, should join me as my fellow editor. He was then editing *Endeavour*, an international quarterly issued by I. C. I. which seeks to review current science and its history. I. C. I. undertook to meet the expense of preparing the manuscript for *A History of Technology* provided I could find a suitable publisher. Responsibility for its printing and publication was at once accepted by the Clarendon Press, Oxford.

Dr. Jaffé continued as my research secretary. Mrs. J. M. Donaldson, who had already had much experience in I. C. I., joined the group as general secretary in January 1951, settling near my home in Cornwall and coming to London in the summer months. In the autumn of the same year, Mr. R. H. G. Thomson, whom I had known since his school days and who had recently taken a first in chemistry at Cambridge, became my personal assistant. They both remained for the next three years, when Thomson became an assistant in the scientific department of the National Gallery of Art, of which department he is now director, and Mrs. Donaldson was re-absorbed into the secretarial staff of I. C. I.

I later enlisted as editorial colleagues Dr. Rupert Hall, then Lecturer in the History of Science at Cambridge and now Professor at the University of California (Los Angeles); and soon after, Dr. Trevor Williams, who has now succeeded Dr. Holmyard as editor of *Endeavour*. Our staff was reinforced by Mrs. Nan Clow, Mrs. Y. Peel, and Miss J. R. Petty, and Miss L. Reeves became the valuable secretary of our London office.

Here then is the scheme as it was originally presented to the directors of I. C. I. The reader can easily see how the plan evolved by comparing it to the tables of contents of the work as published. At an editorial meeting in Cornwall in January 1956, the program for Volumes III, IV, and V was finally evolved.

PROJECT FOR A HISTORY OF TECHNOLOGY

I. *Need for a History of Technology*

Conventional "History" represents a partial way of thinking. The unqualified word history normally refers to political change and evolution. It is generally accepted that there is need for a history based on the evolution of culture as a whole. An attempt at something of the kind is under consideration by UNESCO. Of such a work political history is just the part that is easiest to treat, for its documents are most readily accessible.

The precondition of a satisfactory cultural history is the adequate exploration of its major component elements. Some of these have been well expounded, as, for example, Art, Religion, Agriculture, Architecture, Medicine, and Economics. Scientific ideas too lend themselves well to historical treatment, though the history of science itself, that is of the exploration of Nature, is still in a disjointed state. No considerable attack has been made on a History of Technology. There have however been several effective attempts to put together the main data in dictionary form, and these will be helpful in constructing an historical narrative.

A work on the History of Technology would have its proper place in the general organon of learning. It would also be of direct educational value and would provide, along with the history of science, a satisfactory humanistic background for those professionally trained in science or technology. But not only is there no history of technology; there is no reasonably compact body of writings on it to which the student may turn. Without such a work he can neither orient his own studies in the world in which he lives nor learn of how that world has come to be.

A history of technology should be clearly related to human history as a whole. Necessarily it must be a composite work, the combined effort of many writers. But the exposition of the inter-relation of technical developments to cultural and political movements cannot be left entirely to the specialist authors of the sections. A main task of the editors would be to insure that there is adequate indication of the relation of technological processes to their human background. They can do this partly by influencing the authors of the sections or, when necessary, interpolating short indicative sections on cultural or general history.

II. *Some Theoretical Difficulties*

It is appropriate to mention three major difficulties in the construction of a general history of technology.

(1) Technological skill is not closely related to "civilization" as that word is commonly understood. Two examples will suffice to illustrate this point. Western civilization is regarded as a direct outgrowth of Graeco-Roman civilization. But technologically Graeco-Roman civilization was a decline on that of the ancient Eastern Empires. Again the centuries immediately succeeding the fall of the Roman Empire are thought of as a progressive decline. Technologically this is a misrepresentation. It is necessary only to recall the Sutton Hoo hoard which exhibits a technical skill equal to the very highest Graeco-Roman achievement. Such examples could be multiplied indefinitely. Technological history does not fit easily into conventional "historic" chronology.

(2) Technological periods, technological ideas, and the diffusion of technical devices cannot be separated as easily and distinctly as the periods, ideas, and

diffusion of pure science. Nevertheless technology and science have become inextricably interwoven in the last two centuries.

(3) The introduction and diffusion of technical devices—either with or without scientific foundation—must always have had some relation to general economic conditions. These have at least as much significance for technological as for political history. Thus technological history cannot be written entirely detached from economic factors, as can, for example, the history of scientific ideas.

III. *Some Practical Solutions*

In writing any history, and notably that of a new subject, an initial difficulty is classification of material. Human affairs do not accommodate themselves exactly to centuries and "periods," though these abstractions are a necessity for purposes of exposition. In the draft of our undertaking we adopt a primary division based on chronology, a secondary division based on "civilizations," and a third based on a variable relation of technological devices to each other. The final division into chapters is based on the development of groups of comparable devices that are historically related to each other.

The authors of the chapters will be working in very different intellectual climates. They cannot be asked to adjust their treatment to a too exact plan. Thus it would be useless to expect a writer on palaeolithic industry to fit his scheme into one suitable for the discussion of the state of industry at the 1851 exhibition. There are however certain themes that every author should have in mind. Perhaps the most notable is the necessity of giving throughout clear ideas of the tools and instruments in use in the techniques under discussion. This has never been done adequately and has hardly been approached since Diderot's great *Encyclopédie*. Figures illustrating the precision of the tools and instruments in use should always be given. To do this is to introduce a systematic consideration of the margin of error into history. This idea is fundamental for the criticism of the achievements of past generations, for no one has ever done better than was permitted by his tools and instruments. Conversely, the exactness and even the nature of the tools and instruments may sometimes be inferred from the technical results. This is notably and happily the case where literary records are absent or fragmentary, as, for example, for the "Dark Ages" in Europe, and especially with metal work.

Other points that every author may be asked to bear in mind are the methods of record, the power resources, the metallurgy, and the possibilities of building, lighting, and heating of the period for the subject that he treats. For later times—from about 1500 onward—a flexible framework for the chapters can be devised along such lines as these.

It is proposed to set out the history of technology in a work of five volumes, each of about 1,000 pages of about 350 words each. The task is designed to extend over about five years. The subject demands careful and extensive illustration, and provision must be made for this.

Publication is likely to present neither difficulty nor expense. There is reason to believe that the Oxford Press would shoulder the expense of publication and give a royalty if the manuscript be delivered to them in a tolerable state. We anticipate the production of the first volume in 1951 and of the remaining four volumes in the succeeding three years.

The plan which follows does not indicate the division into volumes. This

will be determined after the number of pages has been assigned to each chapter. It also does not indicate the interpolatory matter that will be added by the editors. The amount and character of this cannot be determined until the material for the chapters is in hand, but it will not be extensive. Of the 1,000 pages of each volume, about 100 would be occupied by figures, bibliography, and index.

IV. *Provisional Table of Contents*

A. FROM PALAEOLITHIC TIMES TO THE ANCIENT EMPIRES (to 500 B. C.)

I. Brain, Hand, and Eye
II. Oldest Tools (from natural materials)
  (a) Technique for working stone, bone, and wood
  (b) Specialization of tools, including Fishing and Hunting Appliances, Palaeolithic and Neolithic
III. Correlation of Human Types and Artifacts
IV. Early Industries involving Artificial Materials
  (a) Pottery
  (b) Textiles
  (c) Leather, etc.
  (d) Building in Wood, Stone, and Brick
  (e) Food Conservation and Preparation, Brewing
V. Beginnings of Metal and Metallurgy
VI. Transport, Communications, and Animal and Mechanical Power
VII. Rotary Motion and Repetitive Machines
VIII. The Urban Revolution

B. THE CLASSICAL WORLD AND ITS HEIRS (500 B. C.-A. D. 1500)

Necessities

IX. Food Conservation and Diet
X. Textiles
XI. Heating, Lighting, Firemaking, Cooking, Cooling etc.
XII. Building and Building Materials

Engineering and Mechanical Aids

XIII. Power Resources
XIV. Mechanical Devices: Pulleys, Pumps, Cog-wheels, Screws, etc.
XV. Irrigation, Drainage, Water-Supply, etc.
XVI. Communication
XVII. Mining
XVIII. Metallurgy and Products of Mines
XIX. Trade Routes

The "Surplus" Arts

XX. Ceramics, Pottery, Glazes, and Glass
XXI. Dyeing and Finishing. Pigments
XXII. Writing Materials
XXIII. Organic Products: Waxes, Resins, Gums, Glues, Soap, Tallow
XXIV. The Finer Arts: Jewelry, Burning Glasses, Fine Tools, Mathematical Instruments, etc.
XXV. Measurement of Time and Space

The Western Heirs of the Classical Tradition

XXVI. Arts of the Wandering Peoples to 800 A. D.
XXVII. The Carolingian Revival, 800-1100
XXVIII. The Medieval Stabilization, 1100-1400
XXIX. The Eastern Contribution, 1000-1500
XXX. Metals and Mining
XXXI. Dry-Salting
XXXII. Weaving. Wool, Linen, Cotton
XXXIII. Silk and Silk Trade
XXXIV. Cast Iron, Steel, and Steel Supply
XXXV. Medieval Clocks
XXXVI. Mercantilism and the National Organization of Industry

C. *IMPACT OF ORGANIZED SCIENCE ON TECHNOLOGY (1500-1800)*

The Forerunners

XXXVII. Paper and Printing
XXXVIII. Mining Developments in the XVth and XVIth Centuries
XXXIX. Increased Production of Cast Iron and Steel (to 1700)
XL. Mechanics becomes a Science
XLI. Assaying and Beginnings of Scientific Chemistry (to 1700)
XLII. New Factors in the Construction of Ocean-Going Ships
XLIII. Search for Raw Materials and Opening of the New World

Mechanical Devices

XLIV. Aids to Calculation (to 1650)
XLV. Rise of Mineralogy (to 1650)
XLVI. The Learned Societies and the Technical Arts (to 1750)
XLVII. Pendulum Clock, Spring Watch, Chronometer
XLVIII. Optics and Optical Apparatus
XLIX. The Lathe
L. Ballistics and Gun-Making

Mass Production by Hand (to 1700)

LI. Sulphuric Acid and Sulphates
LII. Nitre
LIII. Flint Glass
LIV. White Lead and Red Lead
LV. Soap and Tallow

Period of Steam Power from Savery to Watt (1700-1800)

LVI. Coal and Iron Mining in Eighteenth Century
LVII. Development and Application of Steam Engine
LVIII. Power Production of Manufacturing Materials
LIX. Chemical Analysis
LX. Rise of French Chemical Industry
LXI. Improvements in the Steam Engine (Savery, Newcomen, Watt)
LXII. Geology and the Search for Raw Materials
LXIII. The Chemical Revolution

D. SCIENCE TAKES OVER TECHNOLOGY (1800-1850)

LXIV. The Chemical Revolution becomes Industrial
LXV. Mechanisation of the Textile Industry
LXVI. Soda and the Soda Industry
LXVII. Hydrochloric Acid. Chlorine. Bleaching
LXVIII. Dyeing. Dyes and their Active Principles
LXIX. Coal-Gas Lighting
LXX. Coal-Gas By-Products. Tar, Ammonia, Sulphuric Acid
LXXI. Fractionization of Tar-Pitch, Creosote, Carbolic Acid, Anthracene, Naphtha, Benzene, Tolnene, etc.
LXXII. Reform of Agricultural Chemistry
LXXV. Utilization of Waste Products. Ammonia, Sulphuric Acid, Alum.
LXXVII. Beginnings of Photo-Chemistry
LXXIII. Organic Analysis and Synthesis
LXXIV. Steam Locomotion and the Development of the Railway Network. Improvements in Printing and Illustrating

E. ERA OF DOCTRINE OF ENERGY (1850-1900)

LXXVIII. The Doctrine of Energy
LXXIX. State of Industry at the 1851 exhibition
LXXX. The Metals
LXXXI. Nitrates
LXXXII. Petroleum
LXXXIII. Fractionization of Petroleum, Paraffin, Petrol, Gasoline
LXXXIV. Explosives
LXXXV. Beginnings of Internal Combustion Engine.
LXXXVI. Technical Plant, Filter Presses, Evaporators, etc.
LXXXVII. Sugar, Starch
LXXXVIII. Sulphuric Acid. Nitric Acid. Chlorine
LXXXIX. Fermentation Processes and Micro-Organisms
XC. Catalytic Processes in Industry
XCI. Industrial Alcohol from Starch
XCII. Mortar
XCIII. Phosphorus and Matches
XCIV. Rubber and its Vulcanization
XCV. Coal-Tar Derivatives
XCVI. Electric Power enters industry
XCVII. Rise of German Chemical Industry
XCVIII. Technical Education
XCIX. Technical Journals and Literature

This then was the original draft of the scheme. Holmyard retained his activity in the work until its completion in 1958. It gave me particular pleasure to collaborate with him, not only for our old-standing friendship, but also because he had many kinds of knowledge which I lacked. From beginning to end his was the last hand that touched the proof sheets. For the first volume we had the constant and most

valuable help and interest of Sir Wallace Akers, then Director of Research in I. C. I. He read every word of the first volume but died in 1954 a day or two before its publication. This was a very serious loss to the book.

At this time London was still suffering badly from the effects of bombing, and the buildings of I. C. I. had been commandeered for government purposes, so we were first accommodated in premises in Dover Street, a turning out of Piccadilly. There we were joined by our two assistants, Dr. Elsbeth Jaffé, and Mr. R. H. G. Thompson. With the addition of Mrs. J. M. Donaldson, we began work at the end of 1950. Few authors of scientific works have found their task as easy as they estimated. Holmyard and I fully realized that the first volume would take us longest—as it did—but we hoped that the remaining four volumes would appear annually, as in the event, they nearly did. The last and fifth volume appeared in November 1958.

Throughout, but especially after the work had been duly planned, the first difficulty was the finding of suitable authors. It was difficult too, at this stage, to get contributors to understand fully the nature of our undertaking. Fortunately for Volume I, I had the advantage of frequent association with two scholars of unusual vision, the late O. G. S. Crawford and the late Professor V. Gordon Childe, with both of whom I was in almost daily intercourse. The work as a whole and not only its first volume owes much to the guidance and vision of these two remarkable scholars.

From the first Holmyard and I agreed that a feature of the volumes should be good clear figures, always in line-drawing, if at all possible. Only thus could they become an integral part of the text. Almost all of these figures were especially redrawn for the work. In some cases, for various reasons, line-drawings were impracticable, and we had to resort to photographic half-tone plates. In the entire work there are more than 2,500 line figures and 200 plates. We had to employ about a dozen artists, but we had special help from Mr. D. E. Woodall who did far more for us than any other artist.

Perhaps I might be allowed to interpolate here a contentious paragraph on the advantages of redrawings over half-tone plates, however good. It is often argued for the latter that they are "truer to nature." This claim is fallacious save for objects that have not before been reproduced, and then a history is no place for them. The object of a text-figure is to make plain the author's meaning. Anyone who doubts the justification of that meaning should go to the object or its photograph or half-tone representative. The great advantage of a special drawing is that it takes the object represented out of its original context, which is often—perhaps usually—quite different from that in a history or text-book. To me it seems that this principle is important for the history of science and/or technology and is worth emphasizing.

By the time that we had reached the third volume I was in my 81st year and naturally took a smaller share in editing than formerly. Perhaps, therefore, my colleagues' names should precede mine for the last three volumes. However, we met regularly to the end. Though we naturally had differences of opinion, they were never of a serious character. As the reader may see, the final shape of the work was not far from that originally drafted.

It would be out of place here to enumerate all those to whom the work is indebted. But, apart from the authors, I would not like to close without mentioning the many suggestions received from Dr. and Mrs. Archibald Clow of the B. B. C. and several members of the staff of the Clarendon Press, notably Mr. A. P. Norrington, Mr. Colin Roberts, Mr. A. M. Wood, and Mr. Bernard Gosling. Finally, I must add that both the book and I personally owe a very great deal to Dr. Trevor I. Williams and Sir Walter Worboys, without whose great administrative abilities the completion of the work might have been delayed for years.

"A HISTORY OF TECHNOLOGY": SOME EDITORIAL REFLECTIONS

A. RUPERT HALL*

I cannot speak of the earliest stages of *A History of Technology* because, when Dr. Singer did me the honor of inviting me to collaborate with him and the late Dr. E. J. Holmyard in its editing, the first volume had been under way for many months. Experience showed, however, that the editorial problems encountered in a work of this kind do not diminish as one proceeds through the volumes.

Many co-operative histories of the general pattern of ours have been completed in the last seventy or eighty years, but so far as I know their editors have been reticent about their methods and their difficulties. We could see what had been done; otherwise the experience of our predecessors was inaccessible to us. We had to be guided by common sense, trying to foresee problems or solve them as the unexpected cropped up. Certainly we made mistakes due to inexperience: at first, for instance, we did not sufficiently appreciate the importance of exact and detailed timetables in an enterprise that was to be completed in a relatively brief period. And quite apart from the

* Prof. Hall, of the University of California (Los Angeles), was one of the editors of *A History of Technology*.

obvious planning considerations—contents of the volumes, selection of authors, and so forth—there are many technical details of book-production, particularly with hundreds of illustrations and bibliographical references in each volume. Even with the aid of an experienced University Press it was not possible to determine all of these in advance, or to avoid in the beginning some waste of effort.

Before saying anything of problems in editing *A History of Technology*, I must first record the great advantages we enjoyed. The most essential was a generous endowment from Imperial Chemical Industries, Ltd. Without such support the book could never have been begun, for I do not believe that any publishing house could have been persuaded to regard it as commercially feasible. In fact there has been a larger demand—very gratifyingly—for our bulky and costly volumes than anyone would have dared to predict; but it required an enlightened outlook to finance a large history in such a young field. Through our association with a great corporation we enjoyed comfortable offices in London and a variety of services which are more usual in industry than in academic life. We were able to obtain advice and assistance from the helpful members of the artistic and photographic departments, the research library, and so on, to an extent whose value can only be appreciated by those who have had concern with the varied needs of editorship. Our connection with the I. C. I. journal *Endeavour*, edited first by Dr. Holmyard and later by Dr. T. I. Williams, who then joined our own team, was also of great service. Throughout, we were extremely fortunate in the patience and ready co-operation of the Clarendon Press. Then again, in team-work of this kind personal relations are all-important. Though it would be idle to pretend that an enterprise can be protracted over several years without differences of opinion occurring, in our case they were always happily resolved. There was solid friendship among all of us. The tributes to those who assisted the editors through the various volumes are no empty formalities; they accomplished an immense amount of laborious research and detailed work of many kinds. I think the others will forgive me if I only recall the name of one of their number here, Dr. Elsbeth Jaffé, whose learning is silently imprinted on every page of the first three volumes. Finally, it is obvious that a history of this sort could not have been put together, at this time, without the assistance of many scholarly friends, to whom for advice and criticism the editors are greatly indebted.

Their help was the more necessary because each of us was venturing into fresh areas of knowledge. Dr. Singer had been occupied for many years with the history of biological science and medicine before he wrote the history of the manufacture of alum (*The Earliest Chemical Industry*); Dr. Holmyard was a historian of alchemy and chemistry; Dr. Williams has written on the history of the British chemical industry and allied topics; my own field was the history of science, to which

I added an interest in the history of military technology. Since none of us was an archeologist we were specially fortunate in having such good friends as V. Gordon Childe and O. G. S. Crawford, while R. J. Forbes was often with us from Amsterdam, with expert knowledge of almost every point in technological history. As none of us was an engineer we were also happy to benefit from the advice of numerous members of the (British) Newcomen Society.

I do not know that our inexperience was altogether disadvantageous. We began with open minds and were all interested in developing a broad view. That we were collectively ignorant of such matters as the precise techniques used in making various forms of flint implements or the complexity of the Jacquard loom may ultimately have been of some service to our readers. We were always intent that our book should be accessible to a wide audience. Perhaps if we had been more universally expert, we might have been read only by experts.

Of course, one grave lack throughout the planning of the *History* was that of expert scholars to write on topics we wished to consider. Some topics were omitted for this reason. Activity in the history of technology has expanded enormously in the last ten years; many new monographs have appeared, new journals and societies have been founded. Yet interest is still unevenly distributed, though perhaps less than it was. The entire history of the steam-engine is known in enormous detail, while the histories of the windmill and watermill that it ultimately displaced remain rather obscure. Historians know far more of land-holding systems than they do of land-working methods. Or again, while the history of ceramics has been intensively studied from the artistic aspect, far less is written on the techniques involved. One could multiply examples. I am far from imagining that it is impossible to obtain information on any one of these topics, as on many others less obvious, but what is known at the present time is widely scattered and is sometimes of a traditional character rather than the fruit of modern scholarship. Moreover, it is not enough to be aware that Professor X is an expert on a particular topic, say, the building of English Gothic cathedrals. For a chapter on Medieval Building, Professor X has to extend far beyond his own immediate field to the cathedrals of the Continent, to castles, monasteries, manor-houses, and cottages. His chapter can only be fully adequate if there is a competent body of knowledge about all these types of building-construction to which he can refer. For no man can be a complete authority on every point of broad topics. All too often in the history of technology, however, the small area illuminated by some scholar's brilliance is surrounded by relative twilight. What is clear in the fifteenth century may be dark in the fourteenth and sixteenth; what may be plain in France is unexplored in Germany and Spain. For this reason some scholars are not unnaturally reluctant to venture outside the limited areas of knowledge that they do know well.

Historians are individuals with their own views of what is interesting to them and what is significant in their subject. But these are not necessarily the same; a scholar may well prefer that which interests him deeply to another problem of which he nevertheless admits the importance. This characteristic is likely to be especially perceptible in a young subject such as the history of technology, where the number engaged is small and the stimulus of each individualistic. Probably no one in the world today is a historian of technology because it offers an academic career, and very few are compelled to acquire a broad knowledge by the necessities of teaching. For many it is an interest, however passionate, aside from their main academic vocation, and so they tend to be concerned with one problem, topic, or field rather than with the subject as a whole. This state of affairs renders the creation of synthetic history more difficult. If one were to edit a co-operative History of the United States, for instance, there would be available an enormous band of scholars working in this field; what is more, each would have a competent knowledge of the whole subject as it is generally presented, apart from his individual specialty, and share with others a fairly developed common view of the structure of the historical development of the United States. Historical synthesis would arise as much as a product of the historiographical tradition as of editorial planning.

It is no detraction from the efforts of contemporary historians of technology, nor from those of the contributors to our volumes, to indicate that a synoptic view of the history of technology is not similarly obtainable as yet. It was never our purpose to provide one, for we did not believe that such a purpose could be fulfilled. Rather we sought to offer a survey of what could be said at a more direct historical level, accepting such imperfections as discontinuities between the chapters of the same or successive volumes. Some reviewers have flatteringly suggested that the editors should themselves have effected a closer historical synthesis; if they had been men of truly universal learning this might have been possible! No doubt some opportunities of this kind were lost through editorial ignorance or caution. Looking back, wiser than I was at the time, I (personally) would now tend to agree that we might have sacrificed some details in favor of contributions taking a more general and synthetic view—though I believe it would have been difficult to find writers able and competent to carry out such commitments, simply because the preliminary work has not been done. It is often easier to see what is desirable than to know how to provide it.

The main heads under which the development of techniques was to be treated in each volume virtually suggested themselves, though the detailed arrangement of chapters was a complicated business, in which we had to take into account the availability of authors and of space. We were not always able to follow our first wishes in these

respects. More broadly, and without entering too much into our own discussions, there were questions of delimitation to consider which must recur in every history of technology. The first is that of periodization. Chronological boundaries are (as we all say) artificial, but every book has to be broken into sections. Most historians would agree that archaic, pre-literate technology is a subject distinct in itself. But, considering only the Mediterranean and European regions, it is arguable where the next temporal division should logically be placed. Future studies may show that there is no certain frontier between the Greek and pre-Greek worlds in technology, though for the present an arbitrary break about the fifth century B. C. seems as convenient as any. In Europe the collapse of the Roman Empire is almost as epochal an event in technology as in political history. After this chronological division becomes highly problematic. One has to look far ahead to ca. 1750-1800 for a definite boundary line, yet there is no real unity in the stretch from 500 to 1750. A break around 1500, conventional in European history and adopted in our work, is not wholly appropriate to the history of technology; it is straddled by far too many developments in machinery, metallurgical techniques, ceramics, and so on, and not least in science. Perhaps we shall ultimately come to recognize that there is a significant unity in the period from the third to the thirteenth century, and again thence to the seventeenth. But this is not the place to discuss such ideas further.

Secondly there are delimitations of content by no means easy to determine. This history of technology has inescapable affiliations with economic history and with the history of science, and its relations with social history are hardly less direct. One may well ask: How have the non-technological activities and ideas of a society affected the development of its techniques? And, how have the techniques affected the other activities and ideas? When we were planning our *History* it seemed to us (and I still think that this view was correct) that we had enough on our hands in dealing with technology itself, fairly narrowly conceived; and that it was not incumbent upon us to traverse the work of the economic, social, or scientific historian beyond what was strictly necessary. We felt that though it would be desirable in the future to attempt to set the development of technology in a fuller historical context, such an enterprise would far exceed our limits and be of doubtful validity at the present. Reviewers who drew attention to this restriction in our volumes were quite justified as to the fact, but they did not sufficiently appreciate perhaps that we were not attempting a version of the universal history of man and civilization. (There was a time when the developing history of science was set in this universal mold; it was to be the "real" history of the human race with the kings and queens and wars left out; there is perhaps some sign that the history of technology is in danger of succeeding to this position of doubtful glory.) Any history that is not universal can be

described as myopic; it is purely a matter of convention that we regard certain kinds of matter as appropriate for constitutional history, diplomatic history, economic history; and the exact content of the history of technology still lacks a conventional definition.

I have already mentioned that in spite of the ample scale of our work, we suffered from quite serious shortage of space. A good deal more material was collected than we could actually print. In the final volume it was unavoidable that we should increase the number of chapters and decrease their length, but broadly our policy of offering contributors reasonable elbow-room has been justified by results. A succession of short chapters on diverse subjects makes poor reading. But when one has settled the questions of number and length of chapters, authorship, and so forth, there remains a problem of presentation that is peculiarly serious in the history of technology, a subject that comprehends more types of specialist knowledge than any other. For while it is comparatively easy for a mining engineer to write on the history of mining for other mining engineers, or historians of industrial chemistry for readers who are chemists, it is exceedingly difficult in a general work to cross these professional barriers, and the more so the later the period. And an account that avoids all technicalities must remain superficial. This point may seem trivial, but it cost us more effort than most, and no doubt caused us to try our authors' patience. The difficulty of communication is real, and it has to be overcome; perhaps it is less commonly realized how greatly it applies to pictures as well as to words. A photograph of a machine is often a mere totem to a person unfamiliar with that type of machine, conveying nothing.

Even with the assistance of authors who loaned material and offered many helpful suggestions the collection and treatment of illustrations was a formidable part of our editorial task. Some of the best historians are not very interested in pictures, nor do they always know the original source of an illustration or the museum in which an object is to be found. No doubt much pictorial material has been "lost" because a manuscript has not been reproduced in facsimile, or because the illustration has not been reproduced in any book or article read in recent years. Many aspects of technological history—like the iron-working of Sussex—seem to be practically incapable of illustration from contemporary sources, and this is especially unfortunate where the literary descriptions also happen to be thin. Then there are technical problems of reproduction. Ideally, the most perfect facsimile is the best; but it should be remembered that the reader is less well equipped to interpret an obscure or confusing figure than the author who uses it, and that the historian has as much right to offer an interpretation of an illustration as of a text. Hence there is good justification for honest and scrupulous redrawing of original materials.

Illustration of tools and trades in all periods is very copious, and

probably only a fraction of it has ever been reproduced by writers on the history of technology; museum objects are also very numerous, and often less easy to find and examine. It would be invaluable to have a *catalogue raisonnée* of such materials, preferably one that could be enlarged from time to time.

The whole bibliography of technology is in a chaotic condition. Studies are scattered in all likely and unlikely places, series and periodicals, some of them only attainable in very large or very specialized libraries. Bibliographical aides—such as Forbes has begun—are very much needed. Bibliography alone, however, cannot supply the raw material of the history of technology, though some of the older literature is rich in original evidence. In gathering such raw material there is still very much to be done, largely because most of the history of technology that has been written, until quite recently, was inevitably based upon the five per cent or so of easily accessible material. It would not be surprising if, were ten times as many cuneiform tablets transcribed and printed as have yet been, we learned much more of Mesopotamian technology than we know now. Archeological research could certainly yield much more than it has, because archaeologists have possessed only a restricted interest in the techniques by which the artifacts they find were made. Many more chemical and physical analyses of objects and materials need to be made. Much archival material, from medieval charters to the records of industrial firms, awaits exploration by historians of technology. A recent study like that of L. A. Moritz, on grain-milling in antiquity shows how much can be gained by digging beneath the conventional sources. And in many cases at present, even when the essential facts are pretty well known from the raw materials of history, there is still much that demands explanation. Our own *History* is full of unanswered questions. We know that one device or technique succeeded another without understanding anything of the reasons or the manner of the transition. Perhaps many such questions are unanswerable, but historians should not turn their backs on them.

As the detailed monographic treatment of the history of technology proceeds, it will need to be accompanied by further studies of its general development. Some problems of this kind—the influence of social structure or the effect of the development of science—are so vast that exploration of them seems potentially endless; others suggest themselves as more susceptible to straightforward historical discussions. In working on our *History* we were constantly aware of such problems, without feeling we could greatly contribute to their solution. For example, there is the question of the significance of the transmission of techniques from China to the Mediterranean region. Until about twenty-five years ago in spite of much writing based on rather feeble evidence this was in a nebulous state, most western writers agreeing, however, that transmission was unprovable and could safely be set

aside. More recently the case for transmission has been argued much more forcibly by (for instance) Thomas Francis Carter in *The Invention of Printing in China* (1925, 1955) and Joseph Needham in *Science and Civilization in China* (I, 1954; II, 1956; III, 1959). If the sinologists' case is weak, it ought to be revealed as such in work of equal authority; if it be acceptable, it should be supported by other studies based on Western materials. And it goes without saying that the problems of the transmission of technical knowledge within the Western world are equally deserving of consideration.

Another question that impressed me was that of the stratification of techniques within a society. We are usually inclined to estimate the technical proficiency of any people from the finest works it produces; from the magnificence of its architecture, its fine and ornate textiles, the work of its smiths, jewelers, and potters. Our *History* has emphasized the dexterity and skill involved in work of this kind. Nevertheless we know that such products were (in general) used only by the wealthy, while ordinary people used more ordinary goods; and we recognize also that the productive capacity of a society in agriculture, mining, and metallurgy may depend more truly on its mastery of cruder techniques than those of the most skilled artisans. Is there a possibility here of confusing two standards of value? For we find in the later Middle Ages that Islam seems to surpass Europe in the fine crafts, whereas in the use of power Europe excelled. One cannot in such a case say that the technology of one region was superior to that of the other, though one might judge that the European was more progressive in its early exploitation of new and potent principles of manufacture, even if the quality of its products was inferior. The truth is, obviously, that superb artifacts may be produced by unsophisticated techniques, and very poor ones by the most elaborate techniques. The historian needs to know, not merely what the technological resources of a society were, but how they were distributed, for the best may be (like medieval steel) very confined.

This induces me to suggest far less is known of the transition from craft to mechanical production than is to be desired, except in its economic aspects. From the sixteenth century onwards the machines themselves can be described with fair confidence, but before that the details of machine-construction are rather vague, or non-existent. But we know very little of the first steps of design and experiment in machine-making, and of the resources available to those who first sought to mechanize manual processes. We know little of the growth of a class of machine-makers, or of the merits and defects of the earliest machines of particular types. While it may properly be for the economic historian to explain why there was, say, an opportunity for the invention of textile machinery in the eighteenth century, from his study of labor, wages, prices, markets, interest rates, and so on, it is certainly for the historian of technology to explain how the resources

and knowledge to meet such an opportunity came to be available. The machine itself is no *deus ex machina* to be taken for granted and not accounted for.

These last are a few examples of the kind of question on which one editor of *A History of Technology* wishes for further information, or, to employ a fashionable misused noun, insights. Not only will the history of technology acquire in the next few years far more accurate information; it will be enriched by developing structure and perspective. If our volumes are in some measure deficient in these last attributes, as with time they will increasingly appear to be, one may without undue conceit suppose that this reflects a similar deficiency in the state of the history of technology at the period when they were written. To say this is in no way to diminish the value of broad and suggestive interpretations of the development of technology that have already appeared, such as Lewis Mumford's. The solid roots of the history of technology as a subject for research or teaching must always rest in the separate histories of crafts, industries, and processes; but a mere compilation of such narratives does not constitute the true history of technical accomplishment. Our main problem throughout was to try to reconcile these two views by trying to determine what sort of shape and structure a more complete, though hardly a fully developed, history of technology might have. If besides compiling information we have given any impetus towards the attainment of a more mature and integrated type of history in this field our work will not have been profitless.

Technology: The Broad Problems

TOOLS AND THE MAN

LEWIS MUMFORD*

I

For the last three centuries, Western civilization has dedicated a good part of its energies to the invention of machines and the extension of their operations into every corner of life. By now, a machine wakes us up in the morning, sings to us, tells us the state of the weather, carries us to work, and continues, throughout the day, to poke its busy nose into all our activities. If one had listened solely to the more hopeful prophets of an earlier day, one would have believed that nothing but good would come of this process. These prophets supposed that man's capacity to shape tools had made him truly human and that the machine—which displaced manual labor and now even performs complicated mathematical and logical operations—would by its own automatic development bring about an earthly paradise. In the nineteenth century, only a satirist like Samuel Butler could allow himself the privilege of suggesting—as Butler did in writing about his topsy-turvy utopia, Erewhon—that a time might come when people would make mechanical invention a crime and banish machines to museums, as an awful warning to the race.

Today, the sanguine Victorian spirit that tied human felicity to mechanical invention and material progress has been dampened. We know better now. On a spring Sunday, along a well-stocked trout stream near any city, one may behold a solid line of fisherman who have abandoned the quaint machines, painted like a lady's boudoir, that brought them there, in order to perform the paleolithic rite of fishing, with the aid of a line and hook whose prototypes, in bone and sinew, belong to that same age. True, machines themselves and the goods they produce keep on coming thicker and faster, in steadily more glossy perfection, but there is currently some doubt that the life lived in the constantly spreading suburbs of Detroit and Schenectady and Oak Ridge shows a comparable improvement. The human equiva-

* Lewis Mumford is the author of *Technics and Civilization*. The reviews presented here are Copyright © 1956 and 1958 by The New Yorker Magazine, Inc. Reprinted by permission of Mr. Mumford and *The New Yorker*. A further article on this topic by Mr. Mumford is due to appear in *The New Yorker* of October 8, 1960.

lent for "automation" is "boredom." While the triumphs of modern mechanization are indisputable, they are not unqualified. If anesthetics have brought about a miraculous abatement of pain in surgical operations, that great boon is very nearly counterbalanced by an undercurrent of rational anxiety that joins an ever wider stream of neurotic anxiety flowing through Western society. Thanks to science and invention, our children have the prospect at birth of living to the canonical age of three score and ten. But, on the other hand, they and we may be exterminated, as though we were so many hundred million bedbugs and cockroaches, if ever the United States and Soviet Russia deploy, on a full scale, all the engines of genocide they have manufactured. In short, the more exquisitely rational the machines of the modern age become, the more irrational seem to become the purposes to which people are prepared to put them.

Plainly, our Victorian ancestors did not anticipate our plight. If they had done so, they might have spent less time boasting about the mechanical progress they had made and more in trying to understand the origins of technics and its special place in the human economy. But they were the victims of their own mythology. From the time of Francis Bacon on, forward-looking people had been inclined to equate mechanical invention with civilization itself and to assume, further, that the machine would take over the functions that had belonged to art and government. The arc light was heralded in popular cartoons as an agent that would do away with night-time crime more effectively than a policeman, and when James Watt finally perfected a mechanical process for sculpturing the human head, he doubtless felt that the era of the old-fashioned sculptor was over. Strangely, this Victorian pride in the machine went hand in hand with an indifference to its cultural background. The literature in English of technical history has remained singularly meagre down to our own day. Apart from a handful of books by Andrew Ure, Samuel Smiles, and Charles Babbage, the mathematician who invented the first cumbrous mechanical prototype of the electronic computer, there was nothing that could compare with Sigfried Giedion's fascinating modern classic *Mechanization Takes Command*. Karl Marx, it is true, in a few brilliant pages in *Das Kapital* that ranged back to antiquity, laid the foundations for technical history, but only during the last half century have scholars begun to take possession of this field.

The Victorian lack in interest in the cultural history of technics was due partly to a naive pride that was founded on error; i. e., the belief that what had happened before the eighteenth century in England was not to be taken into serious account, so far had earlier technical achievements been outstripped by the great technological inventions that brought the steam engine, the power loom, and the factory system itself into being. But another reason for this lack in interest was that the necessary spadework in technical history had not yet been done,

largely, perhaps, because of a ruling-class belief that its own special trades of war and politics were the only respectable subjects for history. Thus, such a monumental history of technics as the one now before me—*A History of Technology: From Early Times to Fall of Ancient Empires*—could have appeared only in our generation. This handsomely designed and executed book, the first volume in a series of five, was made possible by a grant from Imperial Chemical Industries, Ltd., one of those corporate Maecenases whose role in research and education has still to be appraised. Its editors and contributors are scholars of standing, notably Charles Singer, one of the editors, who is an eminent historian of medicine, and V. Gordon Childe, one of the contributors, whose interpretations of the archeology of the Near East have helped broaden the whole concept of technical advance by uniting it to the social, economic, and political institutions that accompany it.

To those whose interest lies in a special field, this book has the virtues of a historical encyclopedia, for it is really a series of related monographs, dealing with such topics as the origins of toolmaking, primitive time reckoning, rotary motion, the utilization of metals, pottery, and textiles—in fact, the standard subjects of technics—as well as topics, such as mathematics, language, and the fine arts, that are too often omitted from surveys of technology. Even those who, like the Elephant's Child, are lured to this book merely by "'satiable curtiosity" will find much of the material absorbing, all the more because the 827 pages of text are backed by 36 halftones and 570 line illustrations that are done as only the British seem to know how to do them for works of this kind—black-and-white drawings that are far more satisfactory than photographs. One may even pick up the smeary trail of the first ad man in this treatise, for one discovers that Egyptologists, stumped in their research by the number of varieties of beer that had been christened, came to the conclusion that many of the varieties were just proprietary brand names, a conclusion supported by the descriptive phrases that identified them—"the plentiful," the "joybringer," and the "beautiful-good." So much highly significant material has been put together in this one volume that one is not disposed to reproach too severely its occational lapses, like the lack of a sufficiently detailed index to cover a text that consists mainly of details.

But this first volume discloses another kind of fault. This fault is that, as a history, it leaves everything to the reader. The editors, who are aware of this difficulty, have apologized for it in their preface and have referred the reader to the social histories of James H. Breasted and Ralph Turner. This suggestion solves only one portion of the problem. For the editors of *A History of Technology* do not seem to have realized that there is a vast difference between a series of monographs, which is their approach to the subject, and a comprehensive technical history that would attempt to put these parts together in a

fashion that would reveal interrelationships, possibly a pattern. To understand the development of technics, one must distinguish between tools (such as knives and axes) and utensils (such as pots and mirrors), between machines (such as the potter's wheel) and utilities (such as buildings, dams, and canals). For lack of a clarification of this sort, the book never brings out clearly one of the fundamental facts about early technical civilizations; namely, that their great achievements in architecture, city-building, and hydraulic control (dams, reservoirs, irrigation ditches, canals, stream diversion) were all of a static nature. The dynamic elements in technics, today represented by complicated power-driven machines, were of course in existence five thousand years ago, but at that time they took the form of standardized, specialized human beings, who were merely replaceable mechanical parts under centralized control and operating in work gangs and armies. Thus, centuries before ancient civilizations had invented the wagon, to say nothing of the simplest prime mover, like the water mill, they had invented "the machine." As long as human bone and sinew were more plentiful than metal, no other form of machine was called for. Just as the first examples of accurate photographic realism, produced by the Dutch painters, antedated the camera by at least a century, so the first example of highly organized machines antedated power-driven mechanical units by four or five millenniums. One misreads the genuine contribution of the eighteenth century if one thinks that "the machine" played no active part in technics until then. In a static technics, men played the part of machines; in a dynamic technics like ours, machines take the place of men.

The failure of *A History of Technology* to rise far enough above the specific facts of technology to provide a bird's-eye view is all the more disconcerting because, in their choice of articles and contributors, the editors have broken with the smug Victorian tradition that treated technics as if it were a self-sufficient realm. A series of articles on speech, language, art, and mathematics happily departs from that narrow concept of technics, and accordingly lends support to a more adequate picture of the nature of man. Up to now, historians and anthropologists have largely followed Carlyle in defining man as a tool-using animal. That definition flattered the practical man of the last century by giving preeminence to that part of human culture he felt completely at home with, but it was actually a one-sided definition, since it focused attention on the material remains of early culture and left out of account non-material elements that may have had even more weight, such as symbols, patterns of conduct, and the organization of knowledge. This long-favored view—with its division of early cultures into eolithic, paleolithic, mesolithic, and neolithic solely on the basis of their stone implements—did not even have technical validity. For one thing, it ignored the fact that the larger part of man's early technical equipment was probably made of perishable organic materials

—sinews, hide, hair, guts, rushes, wood, and gourds, many of which, incidentally, are still in use among primitive peoples. By its very nature, this evidence has vanished as completely as the social traditions and moral codes that must have gone along with it and directed the workaday activities. But the conventional view has also overlooked the persistence of early technical devices at later periods; the safety pin has come to us very nearly unchanged from the Bronze Age, and the good qualities of casein paint, which we have recently discovered, were known to Egyptian painters many millenniums ago. Civilization itself would come abruptly to an end if man's greatest technical invention, language, should be forgotten—a development that almost certainly began, brain anatomists tell us, before man had learned to shape a tool.

This one-sided interpretation of man's nature has had mischievous results, one of which is to make man's whole development appear dependent upon his increased skill in manipulating tools; as Dr. Loren C. Eiseley, of the University of Pennsylvania, puts it, in the *Yearbook of Anthropology, 1955*, once tool-using was associated strictly with intelligence and human ability, the mere finding of a tool on an archaeological site whose date could be established seemed enough to "determine . . . the point at which a monkey has become a man." This reading back into history of man's own too simple faith in technics led to a distorted view of the entire nature of man, even in his most primitive state. When Boucher de Perthes (1788-1868) discovered his paleolithic cave paintings, the leading anthropologists of the time refused to admit their antiquity; they did not believe that people who used such primitive tools as Aurignacian man did could have reached such a high degree of abstraction and aesthetic expression. Many anthropologists still cannot make the proper deduction from this discovery—that man must have developed the symbols of art and language to a much higher degree, and at a much earlier period, than he developed comparable tools and machines. Indeed, he probably could not even have created the wheeled wagon until he had achieved an adequate method of symbolic abstraction.

One of the great distinctions of *A History of Technology* is that it redresses this balance; in fact, the opening chapters point out that there is plenty of evidence in the animal world to indicate that the ability to use tools is by no means a function peculiar to man. In discussing the evolution of technical skill in prehuman species, Kenneth Oakley, author of the first chapter, remarks that the female burrowing wasp uses a pebble to smooth over the ground in which she has laid her eggs, and that the Darwin finch extracts insects from the crevice of a tree trunk with the spine of a cactus. Both are distinct departures from the usual animal characteristic of effecting a physiological transformation, such as the beaver's tail or the woodpecker's bill, in the organism itself. Similarly, an advanced technology, like that of the

ants or the beavers, goes along with a comparable social organization; isolated beaver families, though they gnaw down trees, do not build themselves dams or underwater lodges. However important social organization and technical skill may be in a highly developed human culture, neither of these attributes is a specifically human trait. What sets man off from the animal and insect world is his capacity for making use of the physical tools of survival for purposes that are uniquely his own—to create works of art and religion, fabrications of thought, forms of social life, individuated patterns of personality. Until the modern period, technics was mainly in the service of human purposes of a non-technical nature. Only today has the doctrine of art for art's sake been applied to the machine.

It is therefore no accident that a good quarter of the first volume is devoted to the technology of the fine arts and crafts—graphic art, cosmetics, pottery, textiles, architecture, metalworking, wood and ivory carving. Nor is it an accident that the greatest mechanical feat of antiquity, the building of the Great Pyramid (it would still be a colossal enterprise in this day of bulldozers, railroads, and electric hoists), was pushed through with only the most rudimentary technical aids—the inclined plane, ropes, and sledges—before even the wagon wheel had been invented. One cannot understand the technology of the Pyramid Age unless one understands why, despite all its feats of canal-digging and dike-making and city-building, the biggest technical efforts of the people of that era were directed not toward easing work or multiplying material goods but toward expressing their ultimate feelings and intuitions about life. The Great Pyramid at Gizeh utters but one word, "Eternity," yet that word has been heard longer than any other uttered by man. By the same token, it is not the pressure of technics but our own false subjective evaluation of physical power that causes the leading country of the Western world to put thirty billion dollars a year into elaborate technical preparations for large-scale genocide while it fails to provide sufficient primitive Stone Age equipment in the way of school buildings to carry on the education of the young, although—ironically—an under-trained generation will not have the technical capacity to run the machines we have created.

What *A History of Technology* is saying is that human purpose controls technics, and that it is not true, as so many of the Victorians supposed, that technics operates independently of man's will and desire and automatically shapes human society. If Victorian scholars were right in thinking that the development of tools was alone responsible for developing man's intelligence and making him human, then modern man, if he is to continue on the path of development, must follow the same line: whatever advances the machine advances man's own specific humanity. But the fact is that man developed a highly complicated brain before he developed the symbols, the concepts, and the institutions that could make use of that extraordinary organ, and in turn he

developed language, art, patterns of social behavior, and an insight into organic processes—enabling this omnivorous creature to discriminate between foods and poisons, and to improve the breed of plants and animals—long before he invented the wheel or could work metal. The most important technical achievement in man's history, one that made possible a vast increase in population and the ultimate domination of the whole planet by man, was the Neolithic Age domestication of plants—a process that owes more to biological insight, the observation of habits of growth and fertilization, hybridization, and soil regeneration than to the digging stick, the spade, the hoe, and the plow. Similarly, in our own age, it may turn out that a deeper knowledge of man's past development and his present psychology will lead to a more vital advance than the splitting of the atom. For that matter, the invention of a simple world language would do more for human communication than any electronic device for rapid translation could ever accomplish.

Volume I of *A History of Technology* performs an admirable job of providing abundant data for historical judgment, but it does not put the various parts together in a way that would show the ratio of non-human power to human power, of static to dynamic factors, of mechanical facilities and biological means (foods, liquors, medicines, chemical aids) to political instruments and aesthetic expressions. It is the balance of these elements that produces a sound human culture, and it is the overplaying of one or another part that has so often, in primitive times as in modern times, created a civilization unfavorable or hostile to life. Neolithic village culture probably achieved a better balance of life with its simple technical means than the great centralized urban civilizations of Egypt, Mesopotamia, and China achieved with all their crafts and skills. There is in existence an Egyptian papyrus (strangely labelled a satire by scholars) that hands down a stinging indictment of the miserable life lived by the specialized workers in and around the new cities. A little reflection on documents like this would make us realize that advances in technics are not necessarily associated with advances in civilization, or with a lift in the level of general human well-being and contentment; in fact, there is often an inverse relation. And until such reflections become sufficiently common to challenge current mythology, we can hardly handle the special problem our civilization faces: of controlling the volume and pressure of technics so that our machines, instead of making man subservient to their functions, will respond, in both quantity and quality, to man's proper needs and goals. The most dangerous notion an age of automation can entertain is the belief that machines have goals of their own, to which man must submit if he knows what's best for him. Not the least service *A History of Technology* can perform is to overcome that popular hallucination, from which not even great scientists are free.

II

Most of us have been brought up on a myth about the machine, and it is one that is not quickly seen through, because it has just enough glittering flakes of truth in it to take our attention off the falsehood in which it is embedded. The fable tells us that though man is a tool-using animal, he knew very little about the industrial arts until the Industrial Revolution, in the eighteenth century. Then, suddenly, in Britain, he mastered the arts of mining, smelting, spinning, weaving, road-making, and mass production, and began the transformation of the world around him. He has succeeded so famously that he may even bring about its disintegration. As every schoolboys knows, it all began with James Watt and the teakettle. The only trouble with this account is that the changes in the eighteenth century were merely the crest of a wave that became visible in the third millennium B. C. Those who know what's Watt know that a predecessor, the Marquis of Worcester, got the idea of the steam engine from Heron of Alexandria, and they also know that the main form of power used in factories up to 1820—indeed, up to 1880 in many parts of New England—was the water wheel, which dates from at least the third century B. C.

In this section, I shall concentrate on Volume II of *A History of Technology*—"The Mediterranean Civilizations and the Middle Ages"—for the main roots of Western culture lie in that period, and a knowledge of it helps to correct the lack of perspective in so much of the literature of modern technology. Unfortunately, however, the editors and contributors go gingerly about putting together the pieces; by not giving us a sufficiently generalized characterization of the industrial advances made before 1500, the terminal date of the second volume, they have not anticipated the real change that did take place somewhat after that time. And a summary epilogue that they have provided in Volume III is too brief to make anything like an adequate interpretation, even in retrospect. The second volume is not as exciting as the first, which traces the history of technology from its unrecorded beginnings, but the problems it raises are even more weighty for our own time. While the period covered is from 700 B. C. to 1500 A. D., two important aspects of technics in existence before the latter date—the mechanical clock and the printing press—are not discussed until Volume III, a fact that puts the whole story of time measurement and social synchronization in false perspective. Compared to the achievements of the three thousand years that preceded this period, the main achievements here seem slow elaborations, rather than displays of fresh inventive skill. So, though glass was first used for beads in 2500 B. C. and first fashioned into vessels around 1500 B. C., evidence of the creation of blown glass is no older than the first century B. C.—not exactly a breathless advance by the standards of this century, which in less than a generation has exploited new plastics in every conceivable

form, from bubble domes to toothbrushes. This slowing up of technics after the Bronze Age is a real puzzle, and probably more than one cause must be sought.

Since the editors of this treatise confine their explanations of technical development chiefly to processes that took place within the realm of the industrial arts themselves, they naturally offer no outside clues to this slowdown, and perhaps nothing so substantial as proof can yet be offered. But it happens that the period covered by the second volume coincides with the rise, in the sixth century B. C., of a series of universal, mainly otherworldly religions, beginning with Zoroastrianism, Buddhism, and the mystery religions of Greece, and nothing would be more likely to slow down technical development than a withdrawal of interest from worldly affairs and an attendant contempt for money, power, and material prosperity. If the world is doomed to sin and sorrow, why should anyone bother to "improve" it? Even while these religions were flourishing, however, most people clung to the manifest benefits of civilization, already achieved for the upper classes, at least. The technological improvements that took place during this period were chiefly in the household arts and the fine arts. Instead of radically changing the environment, people sought to enhance the value, through aesthetic design, of familiar utensils and furnishings. True, there was a trickle of invention. The Etruscans, anticipating Marcel Breuer and Charles Eames, turned out bronze furniture and invented the armchair; the Greeks invented bathtubs and showers; buckets and churns built of sprung staves came in during the Iron Age (on the other hand, the barrel, also shaped by compressing wood, has not been satisfactorily dated); and cupboards with hinged doors also belong to this period. Even mass production of pottery and metal, so characteristic of the Hellenistic period (though it had an earlier beginning), was concerned principally with works of art, or with useful objects, such as Grecian urns and vases, whose aesthetic quality seemed as important to the user as their efficiency. There was no lack of technical skill, for it required immense resources to cast the bronze statues for which the Greeks of the fifth century B. C. are famous. But the great emphasis of technology, after the key inventions of the Stone and the Bronze Ages had been made, was on aesthetic expression, not on practical utilization. The Near Eastern textile workers knew the chemical secret—as yet unfathomed—of keeping the silver thread they used in their cloth from turning black through oxidation, and many another ingenuity of discovery has doubtless been lost, partly because the secret was passed on from master to apprentice without being committed to paper, partly because the process itself lost its significance. As long as technics devoted itself to art or religion, it was not neglected by society, nor was it regarded as servile and beneath human dignity. But the utilitarian cult of Prometheus bowed to the religious and aesthetic symbolisms of Orpheus.

Yet even during the classical part of this long period, the useful arts made some progress; in fact, with the aid of Iron Age tools, the Greeks and the Romans and the Persians built walls, tunnels, canals, cities, houses, and factories, at least as good as those of their predecessors in Egypt and Babylonia, and they performed the work with less manual effort. It is only in our own time, as Sir Winston Churchill has sardonically reminded us, that the most advanced modern houses in England have acquired anything like as adequate a heating system as the old Roman system of warming the floor by hot air in hypocausts, and sanitation and drainage are parallel cases. (It was, however, in their new colonial African towns, such as Timgad, rather than in Rome, that the Romans showed what they could do.) But the emphasis in production was on static "utilities," not on machines—on stable and enduring buildings not on mechanisms that quickly wore out or that were replaced by improved models before they wore out. The chief machines of this ancient world were bodies of men, organized and drilled into a single collective mechanism, such as the Sumerian phalanx and its imitators. And the department of military affairs was also responsible for the only comparable inventions—gigantic siege weapons and monstrous cross-bows and slings.

Not that the ancients lacked real machinery aside from the classic simple "machines" like the pulley and the screw; the Greeks invented the lathe, the first precision machine, for turning wooden or metal cylinders, as early as the sixth century B. C., and the water mill was probably invented in Greece before the third century B. C. But the water mill was limited to the grinding of corn, and there was no attempt apparently, to put this important prime mover to all the uses that medieval people put it to, any more than there was a serious attempt to utilize the known power of steam and hot air. No one knows why the ancient world did not further develop the power that was at hand, and Professor R. J. Forbes, who wrote the second volume's section on water mills, does not satisfy us when he suggests that "the social structure and the cheapness of labor frustrated any inventiveness" on the part of the Roman engineers, for much the same conditions held in England in the eighteenth century, with just the opposite results. But in the next sentence he gives a clue that ties up with my suggestion about the orientation of technics toward art and religion: "Their efforts were only too often wasted on showpieces meant to impress the masses at public festivals." Aesthetic elaboration, not efficiency, was the main concern of ancient technics, even when it was used for mass production. To induce awe and admiration in the beholder was an aim of the old engineers—just as the ancient Chinese armies terrorized opposing armies by donning evil-looking masks, instead of relying on firepower alone. At the beginning, technics associated itself with art and magic in the service of political or religious myth, and though it has now sloughed off art and the cruder tricks

of magic, who dares to say that it does not still serve mythical and equally irrational goals?

Why, then, did a significant shift take place in the twelfth and thirteenth centuries, at the very culmination of Christian civilization, despite its other-worldly aims and its concentration of energy on the building of cathedrals and monasteries? The earliest changes toward a machine-oriented technology came from the military; the new one came mainly, it seems, from the ritual and discipline of the monastery. The evidence for this derives from various sources. Werner Sombart, the German economist, was one of the first men fully to appreciate the fact, when he associated the rise of capitalism with the systematic account-keeping of the Benedictine abbeys. Bertrand Gille adds to this general evidence in the present book's excellent chapter on machinery, quoting a passage from the life of St. Bernard about the Cistercian abbey of Clairvaux, through which passed a river that ground corn, filled a boiler where it was heated to prepare beer, worked the hammers that pounded the cloth in the abbey's fulling mill, then entered the tannery, and finally divided into "many small branches" to perform other kinds of work. The ordered life of the monastery, with every hour of the day punctuated by the clock and devoted to a special duty, was the prototype of the modern "working day." The Benedictine commitment to "work and prayer" took the leisure-class curse off work, and the productivity of this system established the economic value of the mechanically regulated life. "To avoid unnecessary labor," as Mr. Gille says, "which reduced the time available for meditation and prayer, all manufactures in monastic hands were mechanized as far as possible." Whereas army drill sought to make men as automatic as machines by abolishing the inner life, monastic discipline sought, through the automatism of machinery, to emancipate the inner life from undue absorption in work, and so to divorce leisure from any sort of meaningful labor. The good monks hardly realized that the final products of this separation would be automation and television.

This change was abetted and hastened by the Black Death, which wiped out between a third and a half of the population of Europe during the fourteenth century—a catastrophe equivalent to a nuclear war, though, happily, not as permanently and irretrievably devastating. The resulting shortage of labor even brought about the wholesale importation of Oriental slaves into Tuscany. But in time it both improved the status of the native worker and increased the demand for machines, so by the sixteenth century the stage was set for the large-scale invention and operation of machines. Here, too, however, the human process of mechanization antedated the mechanical skill of the machine, for the printing press would have been inconceivable, if the monastic copyists had not, over the centuries, achieved precision and uniformity in the shaping of their letters and in the composition of the written page. In other words, it was not the independent invention

of machines that made men more mechanical; it was the mechanization and standardization of human impulses, the creation of machine-minded men, first in the army and the monastery, then in the bureaucracy and the factory, that made is possible to invent and organize mechanical parts that counterfeited the human reflexes. The virtues of the machine –precision, repetition, undeviating order of a limited kind–correspond in the human psyche to the typical manifestations of a "compulsion neurosis." Thus, it is not strange that our machine age took form, after the catastrophic disruption of the Black Death, in an attempt to minimize external disorder and maximize psychological security by means that the Christian Church had not offered–a reaction to total anxiety. Without this impulse to order and uniformity, we might have waited much longer before being confronted by the blessings and curses of a machine age. And if my interpretation of these facts is correct, the moral should be plain, though it contradicts most of the writers on the subject, from Karl Marx to the latest academic popularizer of technology; namely, that mechanical invention does not exist in an independent sphere but is the product of human desire and human consent, often springing from sources quite remote from technology, passing from fantasy to action, finally hardening into orderly habit and routine, yet never entirely free from subjective distortions and irrational pressures.

Hence, a change of faith and ideology would be as capable of retarding technology today as the concern with art and otherworldly religion possibly retarded it in classical times. Some may regard this as a threat; indeed, to those who see man's future solely in terms of artificial satellites, space platforms, and comatose trips to the moon, such a transference of interest to other fields must seem nothing less than damnable heresy, a sacrilege against the cybernetic deity who provides us with a machine-made equivalent for an abundant life. But if the mythology of the machine does in fact issue out of the dark interior where other mythologies have their origin, a countermovement may still take place on a scale even greater than the religious movements of the sixth century B. C. Since modern technics, whether allied with capitalism or communism, has no built-in brakes to control its suicidal acceleration, we must look to the tendency of all living organisms to maintain their own balance to bring about a shift of human interest sufficiently massive to serve as a brake. The fact that most of our contemporaries can no more picture such a shift than the backward-looking Romans of the fourth century could picture the end of the Roman Empire through the dominance of Christianity does not imply that such a change is impossible. That would not mean the end of technics or of further technical improvements; it would merely mean the end of the compulsion neurosis that has undermined the beneficent technical achievements of the last four centuries.

At all events, the great technical awakening of the West dates back

to well before the eighteenth century, and one must associate it not only with the breakdown of such medieval social institutions as serfdom after the Black Death but with a general shift in interest from the hereafter to the here and now. With this went another shift, from the contemplative life of the religious to the active life of merchants, sailors, craftsmen, financiers, and industrialists, and to a growing concern with quantity and numbers. When Jakob Fugger, the J. P. Morgan of the sixteenth century, offered a share of his business to one of his brothers, the latter rejected it because he said it might imperil his soul, but by this time a large part of the ruling classes, at least, thought it was possible to buy their way into Heaven as they bought their way into the royal court. Equally important, doubtless, is the fact that, from the twelfth century on, trade and military adventure brought Europe into contact with technically superior cultures—Arabic, Persian, and Chinese—for the principal inventions that characterize this period (the Persian windmill, Chinese gunpowder and paper, the Arabic-Chinese magnetic compass, and Korean movable type) all came from the East. When one adds to this the chemical knowledge that also came from the East—the very words "alcohol" and "alkali" betray their Arabic origin—it becomes obvious that modern technology is a product of world unification. What happened in England in the eighteenth century was not insignificant, but it would have been impossible without this global development.

Besides providing the material for a more adequate interpretation of technical development throughout history, this admirable *History of Technology* corrects a distortion of the nineteenth century so common that we are usually unconscious of it—an overemphasis on moving machinery and a tendency to ignore the more static arts of architecture and civil engineering, and, particularly, the processes of chemistry. Our modern world is not just a world of machines, it is also a world of chemical processes, and it owes a heavy debt to the primitive arts of the brewer, the vintner, the dyer, and the tanner, from whom we learned the secrets of fermentation, distillation, and antisepsis. If the editors' emphasis on the role of chemistry is due to the sponsorship of the *History* by the Imperial Chemical Industries, of London, we may be grateful for that association. Alcohol was discovered around 1100, possibly at the medical school in Salerno (as the second volume's writer on "Medical Food and Drink" points out), and brandy was prescribed by physicians during the Black Death, with as much scientific cogency as aspirin was prescribed for influenza in 1918. Significantly, it was the brewers and dyers who first used coal industrially, and the further development of chemical processes, initially employed on organic materials, made coal itself one of the largest sources of dyes, medicines, and other chemicals. In some ways, in fact, chemical industries set the pattern for automation, because once the apparatus is loaded and the temperature and pressure are set, the human hand

plays no part in the process, and the number of workers employed, except for upkeep, is minimal.

This second volume of the *History* leaves technology with one foot in the modern age, yet even before the acceleration of invention began, late-medieval technics could not be termed backward in relation to other aspects of human culture. Up to 1500, indeed, it was still true that technics was concerned with statics more than with mechanics, with durable building more than with the production of consumer goods, with art more than with efficiency, with quality more than with quantity, and with the infinite cunning and adaptability and freedom of the human hand and eye (though feeble and limited) more than with the titanic power of the machine, utilizing extra-human sources of energy to drive other machines. But with simple tools and few machines the people of the Middle Ages produced, all over Europe, buildings of incomparable beauty and serviceability, often marvels of sheer engineering. Until the fourteenth century, when overcrowding began in a few big cities like Paris and Milan, the collective result of their industry, the medieval city, was not just relatively but absolutely superior in order and coherence, in the provision of open spaces and nearby recreation areas, in adaptation of means to ends, to, say, either New York or Levittown today.

If medieval people had paid less attention to religion and art, they would doubtless have been able to give more energy to mechanical production, so they might have been better fed in the winter, better shod, and better clothed, and the gap between the poor and the rich would not have been so threatening. But when we add up all the blessings of the machine, we must also note, on the red side of the ledger, the brutal and irrational contents of both our inner life and our outer activities, as they are disclosed in our present feverish efforts directed toward the extermination of the human race. In that light, our overcommitment to technics may seem as dubious as medieval man's overcommitment to his own subjective fantasies. To say this is not to put one age above the other; it is only to indicate that what we have gained in one department we have lost in another. We can travel faster, shoot farther, communicate more rapidly and widely, produce more goods, and exterminate life more effectively than our medieval counterparts. Who can doubt, too, that we have enormously lengthened the probable span of life at birth, and alleviated, in the less crowded parts of the world, the worst miseries of disease and malign accident? But if we have lifted the spectre of starvation, at least in the United States, we have increased the likelihood of random destruction and extermination; if we can travel more frequently, the place we reach becomes ever more similar to the one we left, and the faster we travel the less we are conscious of any change.

To make anything like a final reckoning of accounts on the technical achievements of the modern age would be to take on prematurely a

task one must leave to much later generations—with the pious hope that they may at least live to tell the tale. But it is not too early to characterize the mixed technology of Europe at the end of the fifteenth century, and to say that, thanks to a system that combined handicraft and the tool with mechanization and power machinery, something like a balance had been temporarily brought about, more favorable to human life than anything that earlier technology had achieved, for it no longer rested on slavery and regimentation. The technical lethargy of the previous three thousand years was being thrown off; the printing press had eliminated the class monopoly of knowledge, and in one department after another the material goods that had once been restricted to a small caste were now becoming available to the whole population, through the vast increase in the use of wind, water, and horse power that the previous centuries had brought in. New realms of technics were being opened up at the very moment when new lands were being discovered in the Western Hemisphere. The repopulation of Europe after the fourteenth century, and its colonial expansion after the sixteenth century, stand as proofs of its technical resourcefulness no less than of its animal vitality. Technics itself had become an adventure, and the totalitarian conformity of a later day had not yet entered technics as the spiritual price exacted for its abundance, its security, and its order. Technics ground the organ, but life still called the tune. Ah, halycon days!

THE BEGINNINGS OF TECHNOLOGY

CLEMENT W. MEIGHAN*

From the viewpoint of the anthropologist and archaeologist, the first two volumes of *A History of Technology* are of most interest. Volume I in particular has drawn substantial contributions from well-known Old World archaeologists, and although much of their material has been presented elsewhere, the careful assembly of such thorough scholarship in one place makes these volumes indispensable works of reference. Yet it is obvious that even so extensive a work as *A History of Technology* could hardly present all the information from all points of view, and in this discussion I would like to emphasize those areas of knowledge which are important supplements to the firm foundation provided by *A History of Technology*.

In its first three sections, Volume I sets the stage for all later tech-

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nological developments: Basic Social Factors, Food-Collecting Stage, and Domestic Activities. In general, these provide a good summary of our present knowledge concerning the origins of technology. However, it is important to recognize that ninety per cent of man's history as a tool-making creature is dealt with in less than a quarter of the first volume. This is partly a reflection of the tremendously long time during which tool-making remained at the simplest levels of complexity. It is also an indication that our knowledge of the beginnings of technology needs a great deal of amplification before we can truly understand the critical early developments during which the patterns of human tool-use were first explored. Some important light on the first beginnings of technology has appeared in the short time since publication of *A History of Technology*, most notably perhaps in the verification of crude pebble tools in association with the Australopithecine man-apes of Africa. It is clear, however, that the first ninety per cent of human technological history is more complicated than previously known, and much new knowledge of this major time period remains to be discovered.

Singer's introduction to the first volume delineates the essential scope of the study as "how things are done or made." Hall's introduction to the second volume specifies further: "It is thus concerned mainly with the nature and evolution of processes, techniques, and devices—in fact with technology proper and not with its social and economic repercussions . . . these volumes are perhaps more in the nature of annals than of history proper . . ." With such statement of goals, it is manifestly unfair to criticize these volumes for their shortcomings in omitting much of the possible cultural interpretation of their data. Yet in recognizing the limited goal, we are aware of other goals that remain to be pursued in future studies of technology. And in point of fact, these volumes often go beyond the mere "annal" category to include abundant interpretation, both explicit and implicit. It is in order, then, to examine the work for achievement in these lines.

In terms of the objectives expressed by Singer, the first two volumes come off exceptionally well in their consideration of how things were made but somewhat less well, in my opinion, on the question of how things were done. Particularly for the prehistoric periods, the question of how things were done or used inevitably requires inferences about function and cultural "meaning" for the objects in question. Such inferences, often made in these pages for the earlier periods, are seldom analyzed or given supporting evidence. Compare, for example, the contrasting comments about early metallurgy:

Vol. I, p. 46: "The superiority of copper weapons over those of stone or bone was almost as decisive as that of firearms over bows and arrows."

Vol. I, p. 503: "The advantages of metal should . . . not be exaggerated

. . . For weapons of war, however, metal has the obvious advantage that it is less likely to break at a critical moment."

These statements do not come from the papers dealing specifically with metallurgy, and it is perhaps unjust to single them out. Yet they are typical of the kind of interpretive judgment found often in the writing of the archaeologists represented in this volume. It is not that these statements are contradictory and questionable (which they are), but that they are conclusions unsupported by evidence. Who has experimented with arrowpoints of copper versus those of stone? Lacking this empirical evidence, an equally strong argument can be made that a stone point is sharper, cheaper, and functionally superior to a metal point, and that a simple sharpened wooden shaft is better than either. I feel that the historians writing for these volumes, having access to better data, have been somewhat more analytical in their thinking than the archaeologists. It must be realized that archaeologists really know very little about the efficiency of their artifacts, and indeed can often only speculate about what the objects *are*, let alone how they worked or how well they worked. With complete awareness of the formidable difficulties confronting the archaeologist in his interpretations, I think we can still strive for more careful expression of conclusions.

Having expressed this uneasiness about occasional statements, I hasten to add that this does not invalidate the overall excellence of many articles. The papers by Oakley, Leakey, and Cole provide a good concise summary of our basic understanding. Oakley's discussion of skill as a human possession is, I think, the best short paper on this topic in print. It brings out very clearly that man owes not only his biological ancestry, but also his cultural ancestry to his background as an animal in the biological world. The papers by Leakey and Cole on the working of stone, bone, and wood present a skilled summary of ancient tool-making techniques, but no new synthesis; most of this material is readily available in standard texts.

It is noteworthy that the earliest periods are still mainly understood by analogy to the customs of living primitives. Volume I finds much supporting data (as in the article by Forde) from customs of living people who today use primitive techniques. Ethnologists, however, rarely study the material culture of primitive people, particularly in modern times when such studies are no longer of central interest to anthropology. As a result, the technology of primitives is known largely on a general and impressionistic basis. For the most part, we do not have information that can be quantified to yield conclusions about efficiency, productivity, amount of labor expended in making and using particular tools, and the like. Such information is essential to understanding a functioning technology, and the relative scarcity of these kinds of data suggest two conclusions: (1) Primitive tech-

nologies deserve more study than they have received, and since studies of this kind can still be made in some parts of the world it would be most regrettable if all living primitives became participants in our machine-age technology without detailed records of their own technology being made. We have already lost tremendous amounts of information that could have been got easily even in the last century—ignoring this kind of study for another fifty years will certainly see the remaining opportunities for observation disappear. To students of technological history, it is amazing that travellers, missionaries, ethnologists, colonial agents, and others who have lived in close contact with primitive peoples have almost universally failed to record such fundamental information as:

> How long does it take to make a pot, a bow, a canoe?
> What is the range of tools actually available to a given member of a primitive tribe?
> What sorts of tools are made for specific purposes? What tools are "general purpose"?
> How effective (in terms of food yield and labor expenditure) are hunting devices such as nets, traps, spear, bow and arrow?
> How does technological change come about in a primitive community? What effect does the introduction of a new device have?

Questions of this kind are fundamental to archaeological inference and hence to understanding of the earliest technologies.

(2) Without details of the kind just mentioned, our impression of primitive technology (and all prehistoric technologies) remains vague, general, and "flat." We do not perceive the complexity, the many things that can be accomplished with even the simplest tool, nor the ingenuity and dexterity of prehistoric man. But these features must be present in the prehistoric past, for we find them amply documented in the earliest historical records. Indeed, a principal lesson of these volumes, shown clearly by the accomplishments of the early empires, is how much can be made, and how much accomplished, with the simplest technology.

But the picture is not entirely grim, and some notable contributions have been made to understanding of primitive technologies. In *A History of Technology* itself, there is an abundance of functional interpretation, particularly when we leave the obscurity of the prehistoric past to examine the records of the ancient empires. A good example is the discussion by Forbes (Vol. II, p. 104) of the relative efficiency of hand-mills versus animal-powered mills in Roman times. This kind of reasoning, applied to prehistoric periods, is more difficult but not entirely impossible, as shown throughout the recent book by Clark, *Prehistoric Europe, the Economic Basis* (New York, 1952). This work (cited but not very extensively utilized in *A History of Technology*)

is an invaluable supplementary volume for the prehistoric periods, since it is not only functional in approach but deals in much greater detail with topics assigned only very limited space in *A History of Technology*. Also of interest here may be mentioned a line of technological development recognized by Leroi-Gourhan in *Prehistoric Man* (p. 87; New York, 1957), in which it is shown that ancient flint-chippers obtained only two inches of cutting edge per pound of flint in the Abbevillian period, and that this amount increased steadily to 120-480 inches per pound in Magdalenian times. Hence, regardless of the form of individual tools, there is an underlying trend toward economy of labor and material. Demonstrations of this kind of regularity are of immense importance in understanding prehistoric technology.

New World archaeologists cannot help but look at these sumptuous volumes with a certain envy and the wish that some comparable study was available for the development of aboriginal technology in the New World. Very little real comparison is attempted between New World and Old World developments, and the scattered references to New World material are sometimes in error (as in Vol. I, fig. 530, where the Chimu culture is dated 1200 B.C. instead of 1200 A.D.). From the viewpoint of the Americanist, nearly all of the articles would have been greatly strengthened by a least a couple of bibliographic references and perhaps a paragraph of discussion of the parallel developments in the New World. For example, it would be hard to tell if there were any domesticated animals in the New World from the discussion of this subject. Likewise, the history of plant cultivation is devoted to detailed consideration of Old World crops such as wheat and barley, but omits all mention of the New World crops such as corn or potatoes. (New World archaeologists who restrict the term "corn" to *Zea mays* are disconcerted by the Old World usage, common in these volumes, of "corn" used to mean "grain.") The same absence of comparative material is noted for most of the topical studies such as those dealing with basketry, pottery, and metallurgy. The preface to the first volume mentions that the technological records of the Far East have been almost entirely omitted, but says nothing about the development of technology in the New World. There is always an element of unfairness in criticizing a work for not including material that the reviewer might wish to see, but again, this is an indication of an extensive area for future research. We can hope that now that these volumes are available, perhaps someone will have the initiative and the energy to prepare at least one more volume of this scope summarizing New World technology in the same thorough way.

In sum, we can recognize extensive gaps in knowledge of prehistoric technology, both in time and space. At the same time, one must acknowledge the prodigious scholarship, the great amount of organizational ability, and the generosity of the private subsidy that made these volumes possible. General works of this kind, involving many

people and many points of view, are surely among the most difficult of scholarly tasks. Their successful completion, as in this case, yields a standard reference work that will not soon be replaced.

TECHNOLOGY IN THE MIDDLE AGES

LYNN WHITE, JR.*

The second volume of *A History of Technology* is a milestone in the progress of our thinking about the Middle Ages. The only work in any way comparable to it has been F. M. Feldhaus's erratic and undocumented *Technik der Antike und des Mittelalters* (Potsdam, 1931). The present volume is at least partly documented, and shows far greater scope and exactness of scholarship. A corps of collaborators provide special chapters and sections on mining and quarrying, metallurgy, agricultural implements, food and drink, leather and parchment, spinning and weaving, furniture, ceramics, glass and glazes, industrial chemistry and military pyrotechnics, the medieval artisan, building construction, fine metal-work and coinage, roads and land travel, harbors, docks, and lighthouses, vehicles and harness, shipbuilding, power, with a note on windmills, machines, with a note on cranes, hydraulic engineering, military technology, and alchemical equipment. (A number of topics which one would expect to find in a book purporting to cover the period to 1500 are treated in Volume III: e. g., the mechanical clock, navigation, paper and printing.) This plump tome must be at the elbow of all specialists in the Middle Ages, since it provides, in summary form, kinds of information hitherto so little investigated and so scattered that most medievalists have scarcely known that such problems—much less such answers—exist.

This does not pretend to be a work of synthesis even as regards technology, or to show in any systematic way the relation of technology to the other factors in the historical process. Yet the reader keeps running into curious sets of items which raise general questions. The onager with a sling is first found in the fourth century of our era (p. 713); the hinged flail comes in the fifth century (p. 106); articulated scissors (as distinct from sheers or tongs), in the sixth to seventh centuries (p. 100); and rowel spurs, in the ninth century

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(p. 558). All of these instruments were improvements on earlier forms not involving moving parts. To us the changes may seem rudimentary, but, in preparation for a more complex technology, the shift in the popular notion of "tool" from something unitary to something involving an interplay of elements may have been fundamental.

That this is a pioneer work is best shown by the fact that its editors did not achieve consistency in its attitudes. Singer himself asserts (p. 753) that "the mining-methods of ancient Rome were hardly improved till the eighteenth century," despite the fact that the first chapter of the book demonstrates that by the time of Agricola's *De re metallica* (1556), which codified medieval inventions in that industry, mining engineers had vastly improved methods of draining, hoisting, and ventilating over anything known in antiquity. Again, R. J. Forbes tells us (p. 602) that the Greeks' "practical knowledge of machinery was not surpassed until the eighteenth century," whereas Bertrand Gille (I believe correctly) maintains (p. 649) that the Middle Ages saw "a considerable advance on the machinery of the ancient world." Since classical studies are an older and better developed discipline than medieval studies, it is not surprising that the present volume is more satisfactory in its handling of the Graeco-Roman world than of "the technologically less understood millennium in Europe—and especially Western Europe—that followed the fall of the western Roman power" (p. 774). As a result, many of the generalizations about medieval technology have not caught up with the newly known facts.

Undoubtedly the most widely read chapter will be Charles Singer's "Epilogue: East and West in Retrospect." This may be unfortunate; for his chief theses are highly debatable in terms of the materials presented in the rest of the volume. With laudable intent, Singer is trying to smash the conventional idolatry of classical civilization and the notion that "history" since antiquity is essentially the history of Western Europe.

Our debt to the brilliant and ingenious pre-classical civilizations is enormous; yet can we agree that "the curve of technological expertness tends to dip rather than to rise with the advent of the classical cultures" (p. 755)? One of the greatest of all inventions was gearing, and the Hellenistic age developed its three basic forms: star, crown, and worm. Although the application of gears described in the surviving Greek technological treatises is very simple, Derek J. Price has identified the corroded remains of an intricately geared planetarium of the first century B. C. which he describes in Volume III of the present *History*. Artillery, which began with the Greeks, has been a major and influential factor in Western technology for twenty-three centuries. Even though the horizontal waterwheel (without gearing) may possibly have been a barbarian invention, the Vitruvian mill with its vertical wheel was the first notable power engine, and as such marks a watershed in the history of technology. Moreover, the invention and rapid

spread of glass blowing about the time of Christ is a fundamental matter. And so one might continue. "The glory that was Greece and the grandeur that was Rome" may have been a bit less grand and glorious than some classicists have maintained, but in inventiveness they involved no decline as compared with what went before.

Singer's second point is that throughout the Middle Ages (or at least until the thirteenth or fourteenth century), the center of civilization was not Europe but the East, and that this is true of technology as well as of the other aspects of culture. Joseph Needham's projected many volumes on *Science and Civilization in China*, I (Cambridge, England, 1954), II (1956), III (1959), will doubtless eventually demonstrate that, despite its singular failure to develop many technological items to the point of real efficiency, the Far East has been, after Western Europe, the second most important source of original technical ideas. But at the present time the glittering civilizations of India can be credited, in technology, only with the system of positional reckoning, the concept of perpetual motion, and the nuclear idea of the stirrup: the big-toe stirrup. And what of Byzantium and Islam, which, together with the Latin-Germanic West, are now universally regarded as forming the Trinity of medieval civilization? Save for Greek fire, no one has yet been able to assign any first-rate technological innovation to the medieval Greek culture which centered on the Golden Horn. The prestige of medieval Islam is rightly high among us: Samarkand and Cordova, Bagdad, Damascus, and Cairo were magnificent centers of art and thought, as well as of commerce. But what original ideas and methods did they provide in technology? Their industrial chemistry indeed marked advance over the Graeco-Roman, but no new departures.

The modern historian, like the Frankish traveler to Constantinople or Damascus, may be dazzled by the brilliance of certain aspects of the medieval East. But we must say of it what A. R. Hall (p. liii) says of Roman life: it "was ever supported by the remorseless labour of the many and the costly manual dexterity of the few." General poverty, together with infinitely patient skill in handcraft (these two often supplement each other, for a rich society is careless) combined to create objects of great elegance for the aristocracy. But it was the West, as Singer admits (p. 775), which produced both a new agriculture of revolutionary productivity and that novel concept of a labor-saving power technology which is one of the pillars of the modern world. About 1444 Bessarion wrote to Constantine Palaeologus, despot of the Morea and the best hope of Greek resurgence against the Turks, urging him to send young men to Italy to learn the practical arts. He was impressed not only with Western textiles and glass, but more particularly with the use of water power to eliminate hand labor, for example, in sawing timbers and working the bellows of furnaces. He speaks of improved arms and ships, and of the advanced state of

metallurgy.[1] Whatever the fecundity of the medieval East, modern technology was born of the Western Middle Ages.

No one is competent to review in detail a work so massive and spacious as this, any more than any single scholar could have written it. The following remarks merely touch on matters familiar to this reviewer.

Since Theophilus Presbyter's *Schedula diversarum artium* is one of the chief sources for the study of medieval technology, it is amiss that there is no unity in this volume as to his date. He is first located (p. 12) as about 1100, but thereafter (pp. 49, 64, 174, 315, 351, 358) as about 950. The best present opinion places him not later than the second half of the eleventh century.[2]

Next to the wheel, the crank is the fundamental mechanical device, but the treatment of it is confused. The suggestion (p. 230) that the carpenter's brace may have been known in Egypt under the Assyrian empire is not justified by the remains. On p. 635 it is said that Hero of Alexandria knew the crank, but on p. 677 (correctly) that the crank "was unknown to ancient engineers." Since the first form of crank motion was probably in terms of a rotary quern with a single verticle peg in the upper stone, it is unfortunate that Fig. 74 reproduces Curwen's reconstructions of vanished horizontal wooden quern handles equipped with vertical pegs for which there is no evidence; while Fig. 75 shows Gordon Childe's "Iberian type of quern with slots in the upper stone for two vertical handles." To attach such handles would be singularly difficult, and Childe seems not to have noticed that the excellent Catalan scholar, Bosch Gimpera, from whom he learned of this type of quern, reconstructed the perishable wooden parts properly, i. e., with a horizontal handlebar attached to the upper stone by two vertical pegs in the opposing slots.[3] Thus, it was best suited to reciprocating rather than to continuous rotary motion. Moreover, the statement (p. 111) that "the first certain literary reference to a rotary hand-mill in the Roman countryside is given by Virgil" overlooks the fact that this particular poem, *Moretum*, is not in Servius's list of Virgil's works, and that it is first mentioned in the Murbach catalogue of the ninth-tenth century.[4] Finally, can it be true that the combination of crank and connecting-rod, invented in the early fifteenth century, made its way so slowly that "even in the seventeenth and eighteenth centuries" they were seldom combined (p. 654), when in this very volume Figs. 20, 554, 555 and Plate 8 illustrate this combination as of about 1510, 1556, 1588 and 1617, while on page 205 we are told that the treadle (involving the crank and drive-shaft) was applied to the spinning wheel "about the end of the fifteenth century" —an item, incidentally, for which one would have appreciated documentation, since our earliest previous date has been 1524?[5] The fact that this major history of technology can deal with the crank so cavalierly shows how inchoate the discipline still is.

While the treatment of the use of horses is extensive, it is often inaccurate. As regards nailed shoes, Catullus does not mention one (p. 561): it has long been recognized that this was simply a *solea*.[6] Nor is it true that "they are common enough on sites from the first century B. C." (p. 561), or even (p. 593) that "the horse-shoe penetrated very slowly until its general adoption in the eighth century A. D." G. Carnat, *Le fer à cheval à travers l'histoire* (Paris, 1951, not "1952"), who is cited as authority for the latter statement, finds no valid evidence of nailed shoes before the tenth century and no "general adoption" before the twelfth. As for the stirrup, Arendt's reconstruction (Fig. 509) of a Scythian saddle of the fourth century B. C. with leather stirrups is a fantasy.[7] The statement (p. 92) that "not until the sixteenth century were horses widely chosen for plowing" is called in question by the inclusion of *equi arantes* under the protection of the Peace of God declared at Claremont in 1095,[8] while in Normandy one thirteenth-century document indicates that the peasants were then using horses for plowing to the complete exclusion of oxen.[9]

And there are more miscellaneous matters which might be improved. The suggestion (p. 107) that Polybius indicates use of an overhead sapling-spring is unwarranted: this pestle operating at the end of a rope was more probably worked with a pulley. As p. 232 more conservatively indicates, no such springs appeared with certainty until the thirteenth century. Fulling mills were not first discovered in the eleventh century (p. 216): one is found on the Serchio in Italy in 983.[10] We know that gunpowder began to be corned by 1429[11] rather than about 1550 (p. 382). It is not quite true that "no history . . . can be traced" of the pivoted front axle between the Dejbjerg wagon of the first century B. C., and the fifteenth century (p. 548): we have at least that on the Oseberg wagon of the middle ninth century.[12] The puzzles surrounding Ausonius's water-driven marble-saws (p. 600) and the supposed water-driven hoist under Vespasian (p. 601) have been touched by this reviewer elsewhere.[13] The earliest known European horizontal windmill is not that of Besson in 1578 (Fig. 568), but that in Mariano Jacopo Tacola's notebook of 1438-1450, now Munich State Library, Cod. Lat. 197, fol. 84r. Small trucks on rails may indeed first emerge at the end of the fifteenth century (p. 655), but in Giovanni di Fontana's notebook of about 1420, now Munich State Library, Cod. Incon. 242, fol. 63v, a fire-spouting demoness moves onstage by means of rails. The assertion (p. 699) that "Greek war-machines . . . provided the basic pattern for all war machines before the invention gunpowder" is incorrect: the trebuchet of the late twelfth century (one would like to know the basis of the date "about 1100" given it on p. 724) operated on the principle of counterweights and proved so efficient that it quickly rendered torsion artillery obsolete.

Every reader will discover errors in so vast and novel a book, but he will find, as well, great and unexpected riches which far outweigh

any defects. Charles Singer and his colleagues have put the whole faternity of medievalists in their debt by enabling them to explore in a systematic way a terrain of the Middle Ages which hitherto has been almost inaccessible. Hereafter every medievalist of broad interests will be cognizant at least of the larger problems of medieval technology as he pursues his special studies. Thanks to this awareness, new evidence should now accumulate rapidly, and more exact conclusions be reached.

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[1] A. G. Keller, "A Byzantine Admirer of 'Western' Progress: Cardinal Bessarion," *Cambridge Historical Journal*, XI (1955), pp. 343-348.

[2] Cf. E. W. Bulatkin, "The Spanish Word 'Matiz,'" *Traditio*, X (1954), p. 487.

[3] P. Bosch Gimpera, "Les investigacions de la cultura ibèrica al Baix Aragó," *Institut d'Estudis Catalans, Secció històrico-arqueologica: Anuari*, vi (1915-1920), p. 653, Fig. 490. In *Antiquity*, XVII (1943), p. 20, Childe claims to find further evidence for Iberic vertical quern handles in the excavations at Numantia. Two vertical holes on opposite sides of the upper stone are best interpreted, at least in the early period, as attachments for a horizontal handle. A. Schulten, *Numantia*, II (Munich, 1921), p. 244, claims querns with a single vertical peg hole, but *ibid.*, IV (1929), p. 227, pl. 50, he shows the "best preserved" fragments of such mills: only one has a vertical peg hole, and since only a segment of the stone is preserved, it may well have had a matching hole at the other edge. *Ibid.*, III (1927), pl. 29, 3 shows a pen drawing of a reconstructed quern with one vertical hole, but likewise it has a lateral handle hole!

[4] T. Birt, *Jugendverse and Heimatpoesie Vergils* (Leipzig, 1910), p. 4.

[5] W. Born, "The Spinning Wheel," *Ciba Review*, III (1939), p. 997.

[6] R. Ellis, *Commentary on Catullus*, 2nd ed. (Oxford, 1889), p. 66.

[7] Cf. J. F. Haskins, "Northern Origins of 'Sassanian' Metalwork," *Artibus Asiae*, XV (1952), p. 263, n. 73: A. D. H. Bivar, "The Stirrup and Its Origins," *Oriental Art*, new series, I (1955), p. 61.

[8] Ordericus Vitalis, Bk 9.3, ed. A. LePrevost (Paris, 1845), III, 471.

[9] ". . . omnes illi qui associabunt equos ad carrucam . . ." L. Delisle, *Études sur la condition de las classe agricole* (Evreux, 1851), p. 135, n. 36.

[10] A. Uccelli, *Storia della tecnica* (Milan, 1944), p. 132.

[11] A. von Essenwein, *Quellen zur Geschichte der Feuerwaffen* (Leipzig, 1872), p. 25.

[12] A. W. Brøgger, etc., *Osebergfundet*, II (Oslo, 1928) Plate I; but cf. *Technology and Culture*, I (1960), p. 131.

[13] *Isis*, XLVI (1955), pp. 291-292; XLVIII (1957), p. 77.

THE SCHOLARLY FUTURE OF THE HISTORY OF TECHNOLOGY

ROBERT S. WOODBURY*

Nearly fifty years ago the late George Sarton had a dream—to establish the History of Science as an independent academic discipline. By the time the present author was privileged to become Sarton's pupil at Harvard in 1935 the main elements by which that dream was to be realized had been substantially developed. A rallying point, as well as a source of scholarly results, had been established in *Isis*, and its complement *Osiris* had begun to appear. Sarton's own great *Introduction to the History of Science* was well under way, and the first volume had appeared in two parts. The History of Science Society was vigorous and effective, and other societies and journals in this field were appearing in various parts of the world. In the universities of a generation ago there were, however, only a handful of men able to give full time to teaching and research in the history of science, and only a few more to whom it was a serious avocation. A few institutions offered elementary courses in the history of science for undergraduates, but only the Massachusetts Institute of Technology had an additional array of courses in the history of the particular sciences. In that year graduate instruction leading to the doctorate was first offered by Sarton and Hartner at Harvard.

Today Sarton's hopes have come to full fruition. Although one cannot say that this work was Sarton's alone, no other figure approached his achievements, his industry, and his high sense of duty. Central in the whole movement was his great *Introduction.* In a sense it lies incompleted, but in another sense it has served the purpose he most desired—to provide the scholar with the tools (when supplemented by the Critical Bibliographies in *Isis*), to show where good work had been done, to lay out the fields most in need of further exploration, and above all to set the scholarly standards by which sure foundations might be laid for eventual fruitful interpretation.

The study of the History of Technology is today in much the same state as was the History of Science in the early 1930's—and we have no Sarton! But a beginning has been made, even if sometimes in false directions.

The voluminous Singer *History of Technology* is far from paralleling Sarton's *Introduction.* Sarton showed what had been done, what needed

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to be done, and how to go about doing it—in short, a guide and an inspiration to further solid work. The Singer book is not only inadequate on what has been done, it hides the fact of the scanty scholarly studies on which it is of necessity based, and worse, gives the impression that the History of Technology is really established. It had already been referred to by scholars who ought to know better as "standard" and even "definitive," as if these terms were justified by weighing the amount of paper or by counting the number of distinguished names on its title pages!

To be sure the editors of these impressive five volumes disclaim in the Preface to Volume I any scholarly purpose by describing it as "primarily a contribution to technical education." One may wonder how many "students of technology and applied science," to say nothing of busy engineers, were expected to read through five volumes averaging some 750 pages each in search of "some humane and historical background," much less to purchase these five volumes at $26.90 each!

The editors' purposes were evidently somewhat broader, for they go on to hope "that their work may also prove useful as an auxiliary to the more specialist studies of historians, archeologists, and other scholars." Although they avoid the painstaking work of Sarton's bibliographies by a passing reference to the very inadequate bibliographies which have thus far appeared, they go to some lengths to provide the most scholarly sort of references in their "List of Illustrations, Tables, and Maps," and even to provide a list of "Abbreviations of Periodical Titles," with the full paraphernalia of scholarship.

One reviewer of Volume II suggests another purpose: "It is evident that this fine work will long remain a standard reference book. . . . Its range and the competence of its contributions are certain insurance of its longevity." Let us hope not.

This work is premature. At least another generation of scholarly work on the history of technology should have passed before a work of this size and range was even attempted. Historians of technology will spend the next generation correcting its many errors of fact and interpretation, and two more generations rooting these errors out of related fields whose scholars will assume this book to be reliable. But worst of all, we have here no inspiration or guide to further work, to say nothing of establishment of scholarly standards.

The book is, however, in print. We have it. What can we make of it? With few exceptions, the various articles do not represent original research, merely summaries of the existing literature, and all too frequently show limited acquaintance with existing and recent scholarly studies. It is not the intent of this review, however, to evaluate subject matter or interpretation in each field; that has been left to the experts in the several fields.

The choice of authors for the various articles is rather surprising.

Of the total of some 158 articles or sections, approximately 110 are by British scholars, four by Americans, two by French, one by Danish, one by Swedish, 13 by Dutch, and 28 by authors whose nationality is not identified, but is fairly obviously British. The number of individual authors is slightly different, for several authors contributed more than one article. The Dutch record is largely that of R. J. Forbes, who is credited with more articles and pages than any other single author. There is not a single Soviet, German, Austrian, or Italian representative. Yet half a dozen articles might be mentioned off hand for which a non-British author of equal or better qualifications could have been found. At least one article is known to have been "ghost-written."

However, such a choice of authors would not be serious were it not for the fact that many of the articles reflect this same parochialism in subject matter, in interpretation, and in the literature used and referred to. Technology, like science, is one of the few truly international human activities, and historians of technology had better treat it so.

Within the area and method of treatment set by the editors, some very odd allotments of space occur, as well as some inclusions which seem to stem from a definition of technology which is hardly acceptable for any period of its history. Leaving aside the proportions given on the time scale, which bear little relevance to the importance—technical, social, or economic—of technology at various periods, one may seriously question the proportions of the space given to the various branches of technology.

A confusion of human activities which use certain of the techniques of technology but are not themselves technology, and of other activities which only influence technology, has led to inclusion of much that is of minor significance. One could not deny that technology is influenced by the form of society in which it arises, but why have an article in Volume I on "Early Forms of Society" and then drop the whole topic until the very last article in Volume V? Surely social forms influenced technology in a number of ways between the dawn of history and the close of the nineteenth century. Yet on page vi of Volume II the editors disclaim any intent to deal with the social and economic reprecussions of technology. One may quite properly say that "Speech and Language," "Astronomy and Mathematics," "Reading and Writing," "Time-reckoning," "Precision and Scientific Instruments," and "The Calendar," are all part of the working tools of technology. Technology also contributes to the "Graphic and Plastic Arts," "Furniture," "Enamelling," to fine work in metal, ivory, or wood for artistic purposes, and even to "Domestication of Animals," "Cultivation of Plants," and "Hunting and Fishing," but are these part of technology itself? "Food and Drink" are important to man, but their history belongs in a work of this sort only in so far as they were produced by technological implements, devices or methods. Surely "Whaling"

and the "Preservation of Fish" are not technology. And "Cartography," is this technology? What about "Town Planning," included in Volume III but omitted before and after? The editors seem to have made no clear distinction between technology and the arts and crafts.

One can, of course, make a case for including some of these topics in a history of technology of this size, but one must surely question the space allotted to these topics as compared to others clearly playing far more important roles in history of technology. Are "Food and Drink" so important *technologically* that one can give a total of some 225 pages to them and only 17 pages to "Coal"? Are the technical aspects of the craft arts so significant that one needs about 127 pages for their story but only 23 pages for "Machines and Mechanics"? Is the scientific basis of technology down to 1750 meaningful enough to warrant over 100 pages and yet allow only 19 pages for the story of "Steel"? And does "Cartography" justify over 100 pages in a work in which the "Stationary Steam Engine" gets 17 pages? Surely machine tools since 1850 deserve more than 22 pages, when an equal space is given to "Fish Preservation." In short, the very elements which made possible an Industrial Society are in this book given short shrift in favor of elements of little significance.

What useful purpose does this impressive five volume work serve? To be sure, it will attract attention to the importance of the history of technology, but it is also likely to become a heavy stone around the neck of scholarly progress in these studies. It has already been quoted as authoritative in learned footnotes, even in *Technology and Culture.* Would a student of American History in a scholarly article have a footnote referring to Morison and Commager, or an historian of Antiquity to Breasted's *Ancient Times*? Yet both are far more reliable, because based upon generations of careful scholarly work. In the future let scholars quoting this *History of Technology* beware that their work is not suspected of being amateur.

Technology: Its Branches

BUILDING AND CIVIL ENGINEERING

CARL W. CONDIT*

The chief value of a panoramic historical survey of any branch of technology lies in the presentation of its archetypal forms and the interaction of technical and functional elements that largely determine their evolution. The development of building techniques and civil engineering from their beginnings to the mid-eighteenth century is perhaps the least complex of all the areas of technology because of the relative stability of structural forms and the limited range of methods available for the construction and control of waterways and harbors. With the addition of ferrous metals and concrete to the materials of building, and with the application of the methods of theoretical and experimental science to the design of structures, the extreme demands of the Industrial Revolution quickly and drastically changed most of the traditional modes of design and construction. By the mid-nineteenth century buildings and engineering works appeared in a number, size, and diversity without precedent in the previous history of these arts. A critical estimate of the relevant chapters [1] in *A History of Technology* must rest, it seems to this reviewer, largely on the question of how well the authors have revealed the interaction of technique and functional necessity in the various stages of structural development and the extent to which such a development has responded to the general evolution of technology and science.[2]

Mr. Bradford, in his chapter on Stone Age building, introduces his subject by describing the ecological and cultural factors that affect building and at an early date led to the differentiation of its forms. The climate and the local availability of materials are the chief external determinants, while communal habits, the social organization, the extent of settled or nomadic character, the intangible but powerful influence of myth and ritual, and the level of tool-making skill are the most decisive of cultural elements. This excellent introduction, though necessarily highly condensed, might serve as the basis for inquiry into building techniques at any stage in their history. Technology long ago,

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of course, began to break down the extreme limits imposed by the primitive hand-and-tool techniques of the Stone Age world; yet the same factors, drastically modified in detail and emphasis, still determine the structural essentials of building and civil engineering. More remarkable is the astonishing antiquity of particular building forms. Tectiform huts of bent or sloping poles, solid bearing walls of planks or logs (the log cabin imported from Europe to America in the seventeenth century), rafter-supported roofs, framing systems of posts, beams, and sills were relatively common in Neolithic and Iron Age Europe and all survive with various modifications at the present time. Timber is the one material which is likely to remain in use as long as building itself, and the forms of rib, beam, and column are basic to all construction in wood.

The transition to masonry structures in the Egyptian and Mesopotamian cultures reveals even more strongly the dependence of building on ecological factors. The relatively simple and undiversified structural techniques are well covered in Mr. Lloyd's descriptive presentation. Sumerian and Akkadian construction was almost entirely of rammed clay and brick, the latter originally sun-dried, but usually kiln-dried from the beginning of the third millenium. The basic techniques of shaping in molds, pressing, drying, and laying up seem to have been established in the pre-dynastic period, and the technological conservatism of the Mesopotamian cultures led to their retention throughout the subsequent history of the Sumerian, Akkadian, and Babylonian dynasties. The chief innovations were glazed brick, corbeled domes, vaulting constructed without centering by sloping the rings of bricks, and the extensive use of bituminous coatings for the waterproofing or hydraulic works. The increased use of stone masonry came with the Assyrian hegemony. The most significant achievement of the Assyrian builders was a stone-lined canal constructed in the reign of Sennacherib. The bed of this waterway was composed of a crude concrete of lime, sand, and broken limestone aggregate laid on a heavy coat of bitumen. At one point the canal crossed a stream on a stone aqueduct of corbeled arches. In the few cases where Mesopotamian buildings rested on foundations, the footings were of limestone rubble. For the most part, however, the immensely thick walls of temples and ziggurats bore directly on the soil.

Sun-dried brick appears to have been the dominant material of predynastic Egypt, but the extensive outcroppings of excellent building stone—limestone, sandstone, granite, basalt—led to large-scale masonry work early in the dynastic period. The achievements of the Egyptian builders in the construction of gigantic temples and pyramids are famous, but aside from quarrier's and mason's tools, little is known of the methods of raising and laying blocks weighing more than a thousand tons. An indication of the builder's growing sophistication is the accumulation of fairly accurate empirical knowledge of the gross

physical properties of stone as a building material. The Egyptian architect knew that stone has a negligible tensile strength and that its use for beams and roof slabs had to be limited to extremely short spans. He knew, further, that sandstone can resist bending more effectively than limestone, and thus with the former he could triple the clear span between columns. On the other hand, Egyptian buildings reveal serious technical deficiencies, especially in inadequate foundations and bonding of masonry blocks. The preservation of a fixed routine of building tended to perpetuate errors as well as successful solutions, a defect that springs as much from a purely pragmatic approach as from a conservative habit of mind.

The largely static societies of the ancient kingdoms offered little stimulus to the construction of roads and bridges. There seems to have been no organized road-building, according to Mr. Forbes, until the Assyrian dynasties, and there is no record of bridge-building prior to the Euphrates crossing built by Nebuchadrezzar, a sizable structure of split palm-trunk beams carried on 100 stone piers.

The highly refined architecture of Minoan and Hellenic cultures rested on an extremely simple technical base, simpler, indeed, than the level achieved in Egypt and Assyria at the high point of their structural development. Greek temples, which were destined to provide the prototypes for many public buildings throughout the Roman period and from the end of the Middle Ages to the mid-twentieth century, are characterized by a straightforward system of trabeated, or post-and-lintel, construction perfectly adapted to marble and limestone. The important technical innovation of Hellenic builders was the use of wrought iron for auxiliary beams in places where the span length was near the limit for stone architraves of manageable weight.

The immense superiority of the Romans over all other ancient peoples in technical ingenuity has always fascinated the historian of classical antiquity. Their achievement in the structural arts reached such a level of refinement and complexity that the purely descriptive and chronological approach of the authors begins to break down at this point. A reasonably adequate presentation of the external facts gives rise to a host of questions. That the Romans exploited Etruscan sources for the arch and vault seems well established, as is the fact that they drew on the resources of the Mediterranean world for their wide range of natural building materials. But this tells us little of their own inventive faculty, which by the end of the Republican period produced a quantity and diversity of innovations without precedent in the previous history of building. Most striking, perhaps, is the Roman development of concrete into a first-class building material with a wide range of applications. By means of it they produced a great proliferation of arched, domed, and vaulted forms of a size and variety that were not to be duplicated until recent times. These structural feats are immediately visible and spectacular, but suppressed and often hidden within

the building or bridge are a wide range of buttressed walls, truss framing in timber and bronze, reinforcing and relieving arches of brick, clamps, dowels, and ties, and beneath the floor elaborate systems of hypocaust heating.

What the reader misses in the section on Roman building in Mr. Brigg's chapter is an analytical approach to structural techniques. The great Roman achievements–the arcaded aqueducts under the superintendency of Frontinus, the domed Pantheon, the huge vaults in the *Thermae* of Caracalla, to name a few of the most impressive examples–are distinguished by a remarkably organic character that reveals a well developed sense of the distribution of loads within the structure. The relieving arches in the dome of the Pantheon and the relation of buttresses, engaged columns, and niches to simple bearing wall constitute an organic form in which material is disposed to correspond closely to the actual distribution of thrusts imposed by the load. The extensive use of groined vaults for wide-span enclosures grew in part from a knowledge of the fact that such a vault can resist bending in either of the two horizontal directions, the rigidity of one vault opposing the thrust of that which intersects it at right angles. The most highly developed example of the basic principle is Hagia Sophia in Constantinople, in which the outward thrust of the great central dome is sustained in part by the rigid forms of the peripheral semi-domes. This permanent masterpiece of art and technical skill is dismissed by Mr. Briggs in a single sentence; yet such a structure constitutes the distant prototype of contemporary vaulted and domed construction in thin shells of concrete.

The high level of Roman building was matched by such purely utilitarian works as roads, docks, harbor facilities, and lighthouses. The roads constituted the only true paved highway system of antiquity, and the excellence of their construction is attested by the fact that some have lasted to the present day. As a matter of fact, there was little improvement in road construction until the work of Trésaguet and MacAdam in the eighteenth century. The evolution of the road from the Roman forms to the end of the nineteenth century is well shown in the continuity and fullness of Mr. Forbes's excellent chapters on this area of civil engineering. Harbor works and lighthouses were derived from precedents in major trading ports such as Athens, Alexandria, Tyre, and Carthage. All Roman lighthouses of masonry were smaller variations on the 275-foot high Pharos at Alexandria, the prototype of all masonry skyscrapers. The chief factor in the development of the elaborate works of civil engineering, as Mr. Forbes and Mr. Goodchild properly emphasize, was the Roman genius for organizing man-power, finances, and techniques on a large scale as well as sheer technical skill. The homogeneous character of the Roman state was of prime importance in this respect.

Romanesque building represents a drastic decline from the sophistica-

tion of Roman structural art, but it was not quite as poverty-stricken as Mr. Briggs suggests. The basilica form, taken directly from Roman public buildings, led rapidly to the development of massive vaults marked by the introduction of brick or stone ribs spanning transversely between columns to add rigidity to the long barrel vault. Perhaps the chief omission in this section, which is confined mainly to Norman building in England, is a discussion of vaulting, walls, and buttresses of brick, the major examples being the cathedrals of Albi and St. Sernin at Toulouse.

There is a steady progression from the massive Carolingian arcades and vaults to the light and open construction of the Gothic cathedral, but the evidence seems to indicate that the pointed arch and the ribbed vault represented a decisive break with previous European techniques. Again, although Mr. Briggs gives us an accurate description of the basic structural forms and techniques of Gothic building, he does not see it as the development of framed construction in stone. He deals with the genesis of Gothic form from a positivistic standpoint, emphasizing the derivation of the pointed arch from the necessity of intersecting two vaults of unequal height and span, but the evidence suggests that this is placing the cart before the horse. Construction in ribbed vaults, pointed ribbed arches, and isolated columns and buttresses was developed at Chartres and Durham as an attempt to provide a symbolic image of the mathematical, Neo-Platonic cosmos accepted by the twelfth century theologians. The extraordinary technical possibilities of the form were quickly seized upon by the brilliant and highly trained master-builders of the thirteenth and fourteenth centuries. The Gothic cathedral is another example of organic form in an age which passed long before the development of scientific stress analysis.

Ecclesiastical building in the high Gothic period absorbed most of the creative technical energies of the time, with the result that much secular building as it is exhibited in dwellings, commercial structures, roads, bridges, and town planning is sadly anticlimactic by comparison. In spite of poor sanitary and living arrangements, the medieval transport system was good; indeed, we are surprised to learn from Mr. Forbes's comprehensive account of roadways that the ratio of trading cost to total cost in the Middle Ages was lower than at present. This seems very likely, in view of the extravagance lavished upon modern expressways and internal-combustion motive power.[3]

Mr. Forbes's presentation of hydraulic engineering in the classical and medieval periods is particularly good on the construction of dikes, especially in the Low Countries, where they obviously reached their highest development, but disappointing in the superficial treatment of aqueduct bridges and irrigation dams. In the latter respect, he fails to mention the extremely important achievement of Justinian's engineer, Chryses of Alexandria, who built the first masonry arch dam, at Daras in Byzantine Persia. Procopius has a description of this remark-

able work, which indicates an intutive understanding of the principle of the arch in its application to the impounding of water.

It is ironic that the high quality of Renaissance architecture rested on a technical basis inferior to that of the Middle Ages. Innovations in traditional bearing-wall construction, such as the cantilevered cornice, and the revival of timber-truss roof framing and iron tie rods were of a minor nature. The decisive break with the past came with the creation of the high ogival dome, which became the distinguishing feature of the Baroque church. The first of these structures is Brunelleschi's dome for the Cathedral of Florence, but it was better than a century before the form became common. The question of the origin of this type of dome is perplexing. There was no classical precedent, and Mr. Briggs suggests that it was derived from Persian antecedents. There is some evidence of Islamic influence on medieval building, but how Brunelleschi may have come in contact with eastern sources is a matter of question. From the beginning of dome construction in the Renaissance, the builders understood the necessity of containing the horizontal thrust at the lower periphery of the shell. Brunelleschi used a ring of oak girders, but iron chains were later substituted for wood members as a tension ring. The most impressive exhibition of structural virtuosity came in the seventeenth century with the construction of double and triple domes composed of an outer shell of wood carried by truss framing to an interior masonry dome. Wren's dome at St. Paul's is the primary example, just as his truss framing of the roof over the Sheldonian Theatre at Oxford is the best representative of this kind of construction at the time.

Renaissance and Baroque building reveals one curious paradox, which is properly noted by Mr. Briggs. Many of the leading architect-engineers of the time distinguished themselves in science and mathematics before they turned to architecture, a characteristic conspicuously true of Wren and Hooke in England. But none of the scientific knowledge and mathematical ability of these highly creative men was turned to the development of a scientific structural theory. Yet the period saw the first attempts to develop such a science in Leonardo da Vinci's studies of the strength of loaded struts and beams and in Galileo's pioneer theorizing in the first part of *The Two New Sciences*. The question is worth further exploration, for it offers an illustration of a fundamental element in the history of European science and technology: the traditional lack of any productive relationship between theoretical science and technical practice, the beginnings of a synthesis during the Renaissance, and the gradual development of a symbiotic union following the Industrial Revolution of the eighteenth century.

The masonry bridge was carried to the ultimate stage of its development between the end of the Middle Ages and the last decade of the eighteenth century. This progress appeared in the constant refinement of form, the introduction of elliptical and segmental arches in addition

to the semicircular form of Roman bridges, and a steady increase in length of span. The highest level of architectural and empirical form came with the bridges of Jean Rodolphe Perronet, who was a particularly brilliant representative of the great tradition of French masonry building. The chief innovations of the Renaissance in the construction of bridges were improvements in the founding of piers. The mechanical pile driver, as crude as it was in comparison with the power-driven machine, greatly speeded up this vital but tedious operation, with the result that the Rialto span, for example, set in the unstable soil of Venice, could be founded securely on 6,000 piles. The development of interlocking tongue-and-groove piling made it possible to close off and unwater the bed of the stream by means of a cofferdam so that bonded masonry could be laid up directly from piling or hardpan strata in the bed.

Since the masonry bridges were the major works of the time, Mr. Hamilton naturally concentrates his attention on these. In so doing, however, he does less than justice to the timber forms, especially the trusses invented by Andrea Palladio. Although they saw little use in Europe, they were destined to play an extremely important role in American bridge development before the ascendency of steel. One of Palladio's trusses was an arched form which combined the compressive strength of the arch with the rigidity of the triangulated truss. In the late eighteenth century the American builder Timothy Palmer revived the Palladian arched truss for a series of daring spans which initiated the extraordinary proliferation of timber truss forms in the United States. These bridges constituted the precedents for the multiplicity of truss types that appeared in the early period of iron bridge construction. This entire phase of the development of building techniques is scarcely touched in the present history.

Renaissance engineering appeared at its best in the extensive canal systems of the time, especially those of France and the Lombard region in Italy. Although these systems were the product of continuous development from medieval precedents, their construction involved major inventions in hydraulic engineering. Foremost of these is the summit-level canal, that is, a waterway which crosses a dividing ridge, which was first achieved in the building of the Stecknitz Canal in north Germany at the end of the fourteenth century. Leonardo da Vinci's invention of the mitre-gate for locks, the evolution of the pound lock, and advances in the construction of storage dams were of prime importance. They were carried to the highest stage of development in the great canal system of France in the seventeenth century. The construction of these waterways, largely planned and supervised by Hugues Cosnier, was a triumph of hydraulic engineering. Mr. Skempton's chapter on canals before the eighteenth century is one of the best on civil engineering and provides a model for the treatment of such subject matter within the limits imposed by this history. In its unity,

thoroughness, and above all, its presentation of evolutionary continuity, it stands in contrast to the generally fragmentary and descriptive character of so many of the other chapters.

The Industrial Revolution of the late eighteenth century wrought as profound changes in building techniques as it did in mechanical technology. The structural arts saw such an enormous expansion in the number and diversity of new forms and applications that it is quite impossible to treat the subject adequately by descriptions of specific works. The primary question, then, is whether the authors of the various chapters have substituted an adequate body of generalizations to indicate the main lines of evolution. For the most part, they have tried to do both, but often at the sacrifice of sound organization and profundity. The fundamental transformations which occurred in structural and civil engineering between 1750 and 1900 are implied by the treatment accorded the different fields rather than explicitly stated. The content of the respective chapters thus becomes a body of selected illustrations related to the broad avenues of change.

The characteristics of the revolution in building which occurred after 1750 may be classified into five broad categories, so closely related as to be separate only in the most arbitrary way: (1) The social and economic determinants of the new industrial age led to demands for structures of unprecedented size and diversity. The chief factors were the requirements of manufacture, business administration, transportation, urban housing, and metropolitan water supply. (2) This expansion in the quantity and variety of structures became possible chiefly through the introduction of ferrous metals and reinforced concrete as primary building materials. (3) As buildings, bridges, and dams grew in total size and intricacy, a safe and practical exploitation of the new materials could come about only through the transformation of building from an empirical craft to a scientific technique, and (4) this in turn could be realized only through the establishment of educational institutions and professional societies for the training of engineers and the dissemination of ideas. (5) As wages rose and the scale of building expanded, cost became a formidable item; to meet the demands while reducing the expenses of construction required the application and steady improvement of power tools.

Iron and concrete as structural materials were introduced nearly at the same time in the late eighteenth century. The latter enjoyed a slow but regular growth throughout the nineteenth, but the great age of concrete construction came only in the present century. For all major buildings and bridges, cast and wrought iron and eventually steel rapidly became the dominant materials and ultimately brought with them a revolution in the entire structural and formal character of building. The process that began with the use of cast iron columns in English mills during the 1790's and culminated in the steel-framed skyscraper of Chicago a hundred years later was a homogeneous and

orthogenetic development. It constitutes part of the subject of Mr. Hamilton's chapters on techniques and materials. The major events are presented, including the important inventions in timber construction such as balloon framing, but the organic pattern of successive innovations and the radiation of forms made possible by the use of ferrous metals are again obscured by the wholly descriptive approach and the simple chronological organization. At the same time, one sees the basic theme of response to new challenges—the need for constantly increasing the strength of members, for fireproofing and wind-bracing, and for developing members with the tensile strength necessary to resist bending forces, the last requiring the substitution of wrought iron for cast.

The evolution of iron and steel bridges from the Coalbrookdale arch (1775-79) to the Firth of Forth cantilever (1882-90) is perhaps the most complex chapter in the entire history of the structural arts. And it is here that the growing union of science and technology most clearly manifests itself. The attempt by Mr. Hamilton and Mr. Smith to treat the subject by describing a few selected examples has resulted in the most conspicuous omissions in the history. In the first place, there is very little on the important contributions of French theorists and engineers to the development of the cable suspension bridge. Second, and most astonishing, is the absence of anything on the truss bridge beyond a passing reference to the Warren truss. Yet the proliferation of timber truss forms in America and of their iron counterparts in both Europe and America constitutes the major phase in the evolution of modern rail and highway spans. More fundamental than this is the failure of the authors to form an adequate conceptual principle by means of which the history of bridge construction can be presented in terms of an increasingly scientific response to the multiplying and diversifying physical challenges. The sections on theory, necessarily superficial, are poorly related to the technical problems that the practical builder faced.

Since the rise of concrete as a scientific building material came only in the last quarter of the nineteenth century with the French inventions in reinforcing, it was possible for the authors to give this subject somewhat fuller treatment. Here again, however, the reader feels the lack of an analytical approach which would present the problem and the validity of the structural solutions. Mass concrete was used throughout the century simply as a substitute for traditional masonry under compressive loads. With the rapid spread and increasing size of the masonry dam, however, a new set of problems arose, and with the application of concrete to the impounding of water, both the advantages of the new material and unlooked for difficulties in its pouring and setting began to arise. This subject is touched upon by the authors of the chapters on water supply systems, canals, and other forms of hydraulic engineering, but they treat the matter so sparingly that the

reader is seriously misled on the diversity and long history of the various forms of earth and masonry dams. This is particularly true of the arch dam, which appeared in concrete at the very end of the nineteenth century and thus constituted an improvement of decisive importance for works of waterway control.

The invention of power tools applicable to the processes of construction has usually been overlooked by historians of the building arts, so that even the brief mention accorded them in this history is welcome. Bridge building in particular came to be increasingly dependent on power-operated cranes, pumps, hammers, and rivet guns. Without such devices and the pneumatic caisson, which dates from the mid-nineteenth century, the great steel railway bridges of the last two decades could never have been built. Equally daring were the long tunnels that were successfully completed in the last quarter of the century—St. Gothard, the longest of all, and more spectacular, the underwater tunnels beneath the Severn and the Thames in England and the Hudson in the United States. Tunnel driving of such magnitude and under such hazardous conditions was made possible by the power-driven cutting shield and power-operated devices for installing cast iron rings to withstand water pressure and for placing concrete linings. Finally, the modern asphalt-concrete highway, another product of the late nineteenth century, could be adequately compacted and levelled for internal-combustion vehicles only by means of the steam-driven roller.

The growth of the sciences of structure and elasticity and their systematic application to the practical arts of building could not have been accomplished without the establishment of educational institutions for the training of engineers, scientists, and mathematicians. Mr. Hamilton touches briefly on the beginnings of technical training with the founding of the École des Ponts et Chaussees and the École Polytechnique in France, but this extremely important phase of the history of the nineteenth century is then dropped. The leadership of the French, of course, was everywhere acknowledged, and on the basis of these prototypes schools in England, Germany, and the United States were soon established. As important as the existence of the schools themselves was the creation and rapid spread of scientific training on the graduate level, largely a German achievement in its pioneer phase. The treatment of the subject of education is one of the many places in the present history where the reader misses a unified presentation of theory and practice with proper emphasis on the interrelations of the various parts. The professionalization of science in the nineteenth century, its intimate dependence on the expansion of universities, the resulting symbiosis of science and technology—these and the economic factors on which they rested constitute the very foundation of the modern industrial machine with its enormous productive

power and the host of formidable social problems that have grown up in its wake.

REFERENCES

[1] The chapters of *A History of Technology* which constitute the subject of this review are the following: Vol. I: ch. 12 (John Bradford, "Building in Wattle, Wood, and Turf"), ch. 17 (Seton Lloyd, "Building in Brick and Stone"), ch. 26 (S. M. Cole, "Land Transport without Wheels"); Vol. II: ch. 12 (Martin S. Briggs, "Building Construction"), ch. 14 (R. G. Goodchild and R. J. Forbes, "Roads and Land Travel, with a Section on Harbors, Docks, Lighthouses"), ch. 19 (R. J. Forbes, "Hydraulic Engineering and Sanitation"); Vol. III: ch. 10 (Martin S. Briggs, "Building Construction"), ch. 11 (Martin S. Briggs, "Town Planning from the Ancient World to the Renaissance"), ch. 16 (S. B. Hamilton, "Bridges"), ch. 17 (A. W. Skempton, "Canals and River Navigation before 1750"); Vol. IV: ch. 15 (S. B. Hamilton, "Building and Civil Engineering Construction"), ch. 16, part i (J. Kennard, "Sanitary Engineering: Water Supply"), ch. 16, part ii (J. Rawlinson, "Sanitary Engineering: Sanitation"), ch. 17 (R. J. Forbes, "Roads to *c.* 1900"), ch. 18, part i (Roger Pilkington, "Canals: Inland Waterways Outside Britain"), ch. 18, part ii (Charles Hadfield, "Canals: Inland Waterways of the British Isles"); Vol. V: ch. 20 (S. B. Hamilton, "Building Materials and Techniques"), ch. 21 (H. Shirley Smith, "Bridges and Tunnels"), ch. 22 (J. Allen, "Hydraulic Engineering"), ch. 23 (F. E. Bruce, "Water Supply").

[2] It is true that many of the most impressive works of building art have arisen from aesthetic and symbolic interests, which have often fixed the requirements which techniques must meet, but within the limits of the present history it was not possible to deal with this subject beyond sporadic mention. Thus the idea of functional necessity has been limited, and will be limited in this review, to the demands of utility and structural necessity once the overall character of structure has been fixed by considerations of form and use.

[3] The bibliography at the conclusion of II, 14 is seriously inadequate on bridges. The authors list only one work, Sara Ruth and Wilbur J. Watson, *Bridges in History and Legend*, but this does not treat the subject technically. Much superior for the purpose of the history are David B. Steinman and Sara Ruth Watson, *Bridges and their Builders*, W. J. Watson, *Bridge Architecture*, and C. S. Whitney, *Bridges; their Art, Science and Evolution.*

TOWN PLANNING

STEPHEN W. JACOBS*

Martin S. Briggs' contribution, "Town Planning from the Ancient World to the Renaissance," to *A History of Technology* (Vol. III, ch. 11) chooses to concentrate on practical considerations at the expense

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of aesthetic ones. He considers the scientific side of Town Planning to be demonstrated by good use of advantageous aspects of the site and by the establishment of satisfactory arrangements for housing, traffic, industry, and recreation.

Beginning with the Egyptian town of Kahun, built as a "model industrial community" for pyramid builders of the twelfth dynasty (c. 1900 B. C.), the organized patterns of city development through the ages are described. The concluding account is of the late seventeenth century: the improvements carried out in Paris under Henri IV and Louis XIII, the extension of Amsterdam and the proposals made for the replanning of London after the Great Fire of 1666. In speaking of ancient prototypes, passing reference is made to the Indus Valley cities (Mohenjo-Daro and Harappa) of the third millennium B. C., whose rectangular grid layouts indicate the antiquity of the standard form for trading and industrial communities. The most extensive discussion is of the "third ancient riverine culture" of Mesopotamia, Babylon serving as the example. Entirely rebuilt in the last days of the "new" Babylonian empire, the capital was given its definitive form by Nebuchadnezzar (here referred to as Nebuchadrezzar) who said, "Is not this great Babylon, that I have built for the house of the kingdom by the might of my power, and for the honour of my majesty." In his view traffic, industry, and housing were minor matters. Most of the information about Babylon given here is derived from Herodotus, and reflects Mr. Briggs' interest in building technology. Distinctive features such as the "hanging gardens" and the ceremonial gates decorated with heraldic animals in relief are not mentioned. However, a neat sketch-plan of the city is provided, the first of 24 excellent plans redrawn from illustrations in archaeological and historical publications. These form a very convenient chronological series for those interested in two-dimensional aspects—the historic patterns of formal town building.

From the Near East we move to the Mediterranean world. Omitting the fascinating achievement of the Minoans of Crete ("In spite of magnificent palaces and temple-precincts in the older civilizations, the art or science of town-planning did not come to flower until Hellenic times"), we shift to the fifth century B. C. The father of the city planning profession, Hippodamus, known to have laid out the port of Athens and a new Greek colonial town in southern Italy, duly makes his appearance. His role in the rebuilding of his home town of Miletus is conjectural. However, it might be suspected that he was responsible for the new residential zone to the south of the older port area and for the reorganization of the central business and ceremonial districts along grandiose lines.

The prehistoric Mediterranean courtyard house type which survives in the area today is described as recorded by archaeologists in a planned suburb of Olynthus in Macedonia and the new market town

of Priene in Asia Minor, both of the fifth century B. C. Some reference is made to the extraordinary combinations of forms at Pompeii, but the plan of the city, which represents a similar grafting of traditional forms of antique Italian origin onto the Hellenistic base, is dismissed as less significant than the architecture and decoration. The latter represent a more precious (and unrivalled) survival than the planning elements which have proved more durable and are readily studied elsewhere.

Unfortunately no full blown Hellenistic metropolis is illustrated, but the major features of Ephesus, Corinth, and Antioch are listed. This omission reflects the unsatisfactory state of the literature on the subject. An investigation of the Hellenistic approach to urban design would be of great interest because of the parallel between problems of these earlier internationally minded communities and those faced by the planners of our day. The integration of elaborate athletic, commercial, theatrical, and ritual facilities into the old pattern of the stronghold and craft center would repay further investigation.

As might be expected of an Oxford publication, the discussion of Roman planning centers around the remote provincial examples of Britain. However, this is justified by the relatively complete state of our knowledge of towns like Silchester and Verulamium (St. Albans) whose plans, together with that of Roman London, are illustrated. The status of the various types of provincial towns in the Roman system is clearly explained. These consisted of officially sponsored colonies, or *coloniae*, and important native towns, or *municipia*. (In Britain one of the latter was a civil center—Verulamium—and four, strategically located, were military—Colchester, Lincoln, Gloucester, and York.) In this discussion we get an inkling of the linkages which account for the existence of the city, the roads and fords which make it a convenient place for people to congregate, to exchange goods and services, and engage in symbolic or cultural activities. But as in other descriptions, most of the limited space available is devoted to more or less significant detail about the sizes, names, dates, and materials of the communities, their defensive walls, and their principal streets and buildings.

This procedure, which provides convenient notes about special features, is particularly unsatisfactory when it comes to the discussion of the major Roman centers. Thus there is no mention of the harbor works at Constantinople or Ostia, although the waterworks of the former and the special commercial character of the latter as the port of Rome are well described. Rome, itself, like those other two famous antiques, the castrum and Vitruvius, is given fairly short shrift. However, a Roman fort (castrum) at Ambleside, Westmoreland, is illustrated, and a sentence is devoted to recommendations of Vitruvius, a conservative architect of the time of Augustus whose writings are our major source of documentation about antique planning. Of the imperial city itself, we are told that "Rome was never systematically planned

. . . though the lay-out of the imperial *fora* and several other parts of the city is a model for posterity, the plan of the ancient city as a whole has little significance for town-planning." By this the author presumably means that it was never regularized and made to conform to a consistent geometric pattern on paper by a single bureaucrat in an office. It does not provide a neat instance of the overall application of the Roman system as does a fiat city like Timgad (" shows the gridiron plan in its strictest form . . . the general effects . . . must have been extremely monotonous "). But no metropolis of an enduring kind has been cast in a single mold in this way. And changes made in Paris and London described later are on a smaller and more piecemeal basis than most of the Imperial revisions of Rome. The survival of marble maps and other archaeological data indicate how great was the Roman interest in planning, and particularly the concern for control of individuals and processions via axes and triumphal ways. But, if we are not given much insight into Roman planning achievements at home, we are offered a series of details about municipal services and sanitary facilities of considerable technological interest.

Medieval town planning is briefly treated, the *bastide* towns of France (Monpazier, Carcassonne) and the new towns laid out or rebuilt at strategic locations in England (Winchelsea) in the late thirteenth century being the major concern. The inclusion of Neubrandenberg, a particularly well preserved example, is a happy choice to illustrate the nature of contemporary German procedure. However, one misses any reference to the developmental aspects of medieval city design, the relation of suburban elements to the fortified nucleus. Many of them were devoted to noisy or smelly activities and were segregated (in anticipation of modern zoning) but might eventually be enclosed in a larger ring wall. There is no mention of the competing interests of secular and religious authorities which played a major role in establishing urban relationships, nor of the planning for market activities, whether internal as a service to the community, or external as in the case of fairs or itinerant vendors who generally set up shop at the city gate. Presumably it is because these were customary arrangements, rather than novelties systematically created according to " predesigned " schemes, that they have been considered outside the pale of " town-planning " as discussed here. The insistence on a formal and theoretical approach works best for a discussion of the achievement of the Renaissance, the age which initiated it.

Among the Renaissance theorists, Leonardo da Vinci is quite appropriately given pride of place, but the efforts of his contemporaries to develop ideal towns in starlike forms which have been the subject of a number of recent studies are also mentioned. In the discussion of the more important Italian towns of this period the influence of earlier (mostly Roman) foundations is recognized. Perhaps it was in the interest of simplicity and clarity that these complicating factors were

not taken up in relation to earlier planning developments. In any case, the discussion of Turin is particularly helpful in demonstrating the way in which the seventeenth century extension effected the breaking out beyond the compact fortified Roman settlement to spill into the surrounding areas. A good account is given of the various cleanup campaigns which transformed Papal Rome from a collection of tawdry, if bucolic, ruins into the grandiloquent baroque city we know today. The cutting through of great avenues to create what were considered in pre-automobile days giant vistas, the terminating of them with obelisks and monuments, and the laying down of great plazas in front of major churches and palaces set a pattern which has yet to be superseded for grandiose and official schemes.

For sixteenth century France several instances are given of small towns laid out on rectangular patterns, but the discussion of Richelieu, the state and service town created for the famous Cardinal in the 1630's, is much more impressive. In this case the scheme is described in some detail, with an excellent drawing at large scale and a quotation from John Evelyn about "this pretty town . . . handsomely wall'd about & moated." We are given readable and relatively complete information, rather than the strings of concise but often unrelated notes which are provided in encyclopedia style elsewhere. Curiously enough, the development of Versailles, the end point of the phenomenon seen at Richelieu, is omitted, although two sentences are devoted to the works of Louis XIV in Paris.

Briggs' approach serves him well in accounting for Amsterdam, whose exfoliation in the seventeenth century (when a series of concentric canals were built to reclaim several strips of land connected by radial bridges to the old settlement along the Amstel river below the dam) is one of the great achievements of city planning. Moving over to England, Briggs takes up in some detail the creation of the various squares of London by Inigo Jones and his successors, and the opportunity created by the Great Fire is thoroughly covered. The plan of the city prepared from the survey of the ruins is shown opposite the Wren scheme for the rebuilding of London, making graphic the ingenuity and continental character of the great mathematician-architect's proposals. With an extended account of the friendly rivalry of Wren and Evelyn and the reasons for the ignoring of their schemes in the rebuilding of the city, this account of three millennia of town planning draws to a close.

This article provides a systematic and chronological account of the major achievements of western society in imposing permanent geometric order on cities. It is possible to question the documentary and touristic approach to the problem, an approach which stresses paper patterns and the remains which can be visited today. However, it is impossible not to be impressed with the convenient marshalling of

facts and figures which explain and footnote many circumstances relating to a well selected series of historic town-plans.

If one accepts the author's premise that where they were not "foreseen by town-planners" the patterns of cities must be regarded as "spontaneous expressions of the culture in which they arose," the issue becomes one of "predesign." Unfortunately, the social significance of such a predetermined form and the kind of delegation of authority it represents—in fact its academic qualities—are never made clear except by implication.

CERAMICS AND GLASS

H. J. HADEN*

The fashioning of clay into articles of utilitarian and aesthetic value has been practiced to all intents and purposes from the dawn of civilization. Variations and improvements in the techniques employed have occurred over some five thousand years, which means that each of the five volumes of *A History of Technology* contains a contribution on clay products and the last four have contributions on glass. This parcelling out of the material could cause the reader inconvenience, and naturally the question arises whether the general form adopted by the editors is the best or whether each subject should have been dealt with in one continuous essay preferably by one author, or, if that was not practicable, by several working in close collaboration. This would have obviated the duplication of information which inevitably occurs in the present editorial pattern.

The critic of sections dealing with ceramics and glass has first to consider whether to deal with each subject as a whole or period by period and volume by volume; but although closely allied the production methods for ceramics and glass are so distinct, and each has its peculiar complications, that for the sake of clarity it is advisable to treat them separately.

Pottery, which in its widest sense includes all objects made from clay and baked hard by fire, has—as the late Sir Lindsay Scott, a distinguished British civil servant and author of the first article (Vol. I, ch. 15), says—"no simple origin." Imaginative scholars have tried to

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deduce that the earliest pottery was created in imitation of basketwork or gourds but, as Sir Lindsay is at pains to point out, there is no real archaeological evidence for such a suggestion. That pottery has been produced from very early times and in many parts of the world is something for which archaeologists must be eternally grateful, for it is questionable whether any other product of the hands of man has survived to provide sounder evidence on which to estimate the levels of culture in ages past. For a craft that has been practised continuously from remote antiquity the techniques of production have shown surprisingly few changes, and the task of the contributors to this *History* on the actual mechanics of production must have been singularly unrewarding. The needs or, rather, desires of modern man for phenomenal variety in shape and decoration in his ceramics, and the infinite capacity of servants the world over for breaking them, have meant that the chief technical developments have been in the direction of increasing production and reducing costs by centralization, efficient furnace control, mechanization, and the reduction of waste rather than by radical changes in the processes themselves. Hand-pressing and coiling methods employed before the advent of the potter's wheel are still used by primitive peoples in the more remote parts of Asia and Africa, just as they are by countless children in schools in many Western countries.

Sir Lindsay Scott's article constitutes an admirable introduction to the subject. In it he propounds no pet theories but bases his argument firmly on the evidence that excavation has produced. His approach is cautious, and, indeed, there is good reason for this since the archaeological excavations have the habit of producing new material that disproves dogmatic statements almost as soon as they have been published. One thing is certain, namely, that before a satisfactory history of pottery production in Europe can be compiled there must be many more fruitful excavations, and much work must be undertaken on the chemical analysis of the pots unearthed. Points on which Sir Lindsay does well to touch are the influence of religious and magical beliefs on the ancient potters and the organized trade in pottery. In many respects the studio potter of today pursues his craft as did the ancient potters, and with good reason Sir Lindsay draws attention in his bibliography to *A Potter's Book* (1945), by B. Leach, one of the best of today's British artist-potters. That, as Sir Lindsay remarks, the best technical discussion of ancient pottery-making is still to be found in Louis Franchet's *La Ceramique Primitive* (1911) emphasizes the need for collecting the considerable quantity of scattered information made available in recent years and gives cause for thankfulness for this scholarly contribution.

Volume II (ch. 8) covers in general the period from c. 700 B. C. to A. D. 1500, but in coping with the perennial craft of potting it was wisely decided to split this vast span of years into two, the natural

division coming at the fall of the Roman Empire. The first part is most efficiently dealt with by Gisela M. A. Richter, Hon. Curator of Greek and Roman Antiquities at the Metropolitan Museum of Art, New York; indeed, her contribution is a model of clear and concise exposition of a complex subject and is accompanied by an excellent collection of illustrations, thorough documentation, and bibliography. Archaeological finds are, of course, still the primary sources of data for this period, references by ancient writers being sparse and uninformative, but in some respects material is remarkably plentiful. The author deals first with Greek pottery, c. 700-300 B. C., carefully examining the assumed methods of making the familiar Athenian vases, the techniques of applying painted decoration to the green pot, and firing under oxidizing, reducing, and re-oxidizing conditions. Then the reader is introduced to Hellenistic Greek pottery of c. 300-100 B. C. when moulded relief decoration largely supplanted paint. The third section is devoted to Etruscan pottery, c. 700-100 B. C., especially the interesting bucchero ware, and in the final section the reader is introduced to the important side-line of making statuary and reliefs.

E. M. Jope, Reader in Archaeology at The Queen's University of Belfast, supplies the part concerned with medieval ceramics. During the Dark Ages that followed the fall of the Roman Empire pottery making degenerated, good wheel-made ware declined, and there was a reversal to primitive methods. From the thirteenth century the strongest influences were oriental. Most evidence of techniques come from excavated kilns and pottery specimens. As for the earlier periods, little work has been done on the analyzing of pots and glazes, and what little has been written on the technology of the period is scattered. Mr. Jope serves the reader well with a full bibliography and provides interesting diagrams of reconstructed kilns and valuable data about firing temperatures, but it is regrettable that he does not supply notes on his information sources. After giving sections to Islamic, Chinese, and Byzantine influences, the shaping of vessels, firing, glazes, and ornamentation, he comes to the important subject of bricks and tiles–but here the reader encounters the somewhat extravagant assertion that " the technique of white inlay reached its peak at Chertsey Abbey (c. 1270), Surrey, and Halesowen Priory (c. 1290)." Certainly the few encaustic tiles that have survived from the Premonstratensian abbey at Halesowen do not justify so sweeping a claim. The growth of trade between Europe and the East was chiefly responsible for knowledge of the materials and techniques for the making of fine pottery and porcelain spreading through the Mediterranean countries to Western Europe. More refined vessels were demanded to replace wooden, horn, earthenware, and pewter vessels in the homes of the gentry, merchant, and artisan classes, especially in an England freeing itself from feudalism.

From the fifteenth century on, alchemists and practical potters were

tireless in their efforts to imitate the ceramics of Persia and the Far East, and as knowledge about the properties of minerals, improved methods of preparing raw materials and glazes, and the construction of kilns to reach higher temperatures spread, there resulted the fine tin-glazed maiolica of Tuscan Italy, Spanish faience, German stoneware, Palissy's, Dutch, and Lambeth delft ware, the soft-paste porcelain of Chelsea, Bow, Derby, and Longton Hall, and the rare beauties of the Meissen and Sèvres factories. The literature for the period from the fifteenth to the nineteenth century is enormous and ever growing, and A. and Nan Clows, authors of *The Chemical Age* (1952), in their contribution, "Ceramics from the 15th century to the rise of the Potteries," provide a most praiseworthy summary of a subject of immense complexity. The article is copiously illustrated with pictures of typical pieces from some of the famous potteries that flourished in the period covered. The supplied bibliography could without difficulty be increased several fold, but it would not have been amiss to draw attention to the books on Wedgwood by Eliza Meteyard and Llewellyn Jewitt or the modelled pottery figures that formed an important branch of the Potteries' trade in the eighteenth and nineteenth centuries.

Improved mechanization of the manufacturing processes rather than increased scientific knowledge was mainly responsible for the expansion of the ceramics industry until quite late in the nineteenth century. Though they envied him, competing potters were slow to emulate the capitalistic and artistic enterprise of Josiah Wedgwood, and the industry continued to be dominated by the skilled craftsman. Pressure from a population seeking a higher standard of living and the demand for ceramics for the rising metallurgical and electrical industries necessitated vastly increased output as the reign of Queen Victoria progressed, and in the last quarter of the century a marked improvement occurred in scientific method as applied to ceramics. This significant movement is most competently sketched in Volume V (ch. 27) by Ireen Jameson. Industrial technology as we understand it today was at last, by the influence of laissez-faire capitalism and social reform, becoming a reality. There was Seger devoting his energy to research into clays; there were vast improvements in kiln efficiency through the use of gas; the qualities of masquisite, bentoute, alumina, and moler were discovered; machines were devised for the easier preparation of raw materials—all of which contributed to the mass production of ceramic products, which in turn contributed so much to the health, welfare, and prosperity of people of all classes. This final chapter on ceramics, excellent so far as it goes, is indeed short measure for a period so important in the history of technology of clayware, especially in relation to the earlier chapters which are padded with information not strictly relevant, and it seems a pity that the bibliography consists

of two works only—one French (an English translation has appeared) and one in German.

Commendable though the choice of pictures to illustrate the technology of ceramics is, even greater praise must be accorded the editors responsible for the selection accompanying the chapters on glass. Till the dawn of the nineteenth century the literature of glassmaking was slight indeed, and even today in some branches of the industry manufacturers guard jealously the secrets of certain recipes and processes. The transmutation of dull sand, the ashes of vegetation, and certain minerals into translucent and vari-colored glasses in ancient times inevitably became invested with magical significance. "There is no doubt that Glass is one of the true fruits of the Art of fire," wrote Antonio Neri at the beginning of the seventeenth century in his deservedly famous book *The Art of Glass* (the English version of which was published in 1662). "I will make manifest those hidden mysteries," he proudly announced, and went about his task with laudable circumspection. "The invention of glass (if it may be credited) is most ancient"—a statement with which Dr. D. B. Harden, Keeper of the Department of Antiquities, The Ashmolean Museum, Oxford, from 1945 until 1956 when he became Director of the London Museum, and author of the learned article "Glass and Glazes" (Vol. II, ch. 9), would not disagree—and then Neri continues, "Some will, and perhaps with some reason [say] that the invention of Glass was found out by the Alchymists; for they desiring to imitate jewels, found glass; a thing perhaps not far from true." Dr. Harden, whose contribution sets a supreme standard in erudition and clarity, confesses (p. 314): "We know all too little of how the ancients made glass, and what kinds of glass they made a different periods and in different places. Our insight into their practices is befogged by the darkness that surrounds so many of the more elaborate technical processes of antiquity." Glazed beads dating from c. 3000 B. C. have been discovered in Upper Egypt, but it is not until c. 1500 that glass vessels occur. Glass blowing, it would appear, was not practised until the first century B. C.—almost certainly first in Syria.

Dr. Harden begins with analyses of the chemical constituents of antique glass and details of early samples of glazes and frit. Under sub-headings the reader is introduced to "Glassware to 750 B. C." (e. g. the cold-cut head-rest found in Tutankhamen's tomb); "The first renaissance of glass from about 750 B. C." (mould-pressed and sand-core vessels); "Glass blowing begins, First century B. C." (e .g. the Portland Vase); "Post-Roman glass" (especially of the Rhineland, Gaul, and Britain); and then follow details of materials and implements, and techniques of making and decorating. Precise references are given in support of statements, and these constitute a fairly full bibliography.

At the time of the Renaissance, c. 1500, the period at which Volume

III begins, economic factors were beginning to exert a vital influence on craft industries. Despite the threat of dire penalties intended to deter them from betraying the secrets of their "mystery," the glassmakers of Venice ventured to leave their native land and seek their fortune elsewhere. They came to England, which also attracted Huguenot *gentilhommes verriers* fearful of religious persecution in France. The knowledge and skills of these immigrants resulted in the establishing of glassmaking on an appreciable scale in England for the first time. Before long it had spread to Scotland and Ireland, and glassworkers, as well as exports of glass, were soon crossing the Atlantic to the New World. The historian will warmly approve of Chapter 9 of Volume III in which the period 1500-1750 is covered jointly by R. J. Charleston, Assistant Keeper in the Department of Ceramic and Glass, The Victoria and Albert Museum, London, who is an expert on Roman pottery and has made several notable contributions to the *Journal of the Society of Glass Technology*, and L. M. Angus-Butterworth, director of The Newton Heath Glass Works, Manchester, and author of *British Table and Ornamental Glass* (1956). Among the few early printed sources of information the student must be grateful for Georg Agricola's *De Re Metallica* (Basle, 1556), Neri's standard work *L'arte Vetraria* (1612) with Merrett's English version, and Johann Kunckel's *Ars Vitraria Experimentalis* (1679), and the results of a few excavations of glasshouse sites. The authors emphasize the need for more digging to discover the facts about old furnaces; unfortunately few sites are still accessible; those in the Eccleshall area of North Staffordshire would probably repay further investigation. This long chapter contains no less than nine sub-divisions which cover adequately most aspects of the subject: glassmaking in Italy; the types of furnaces (admirably illustrated—the painting of G. M. Butteri in the Studiolo of Francescio I de Medici, c. 1570, being very welcome); the evolution of the glassmakers' "chair" system; Ravenscoft and English lead crystal; Kunckel and the development of ruby glass; the making and preparing of lens, window, and stained glass. Although the given bibliography is sufficient, A. Hartshorne's monumental work and D. R. Guttery's *From Broad-Glass to Cut Crystal* (1956) are notable omissions, and it would have been useful to give documentary references. It is easy to be side-tracked when dealing with so involved a subject, but the authors might have referred more fully to political and religious influences on the industry. The injustice of the monopoly system, abolished at the time of the Commonwealth, was well exemplified in an anecdote retailed by that prince of gossip-mongers John Aubrey: "Mr. Phillips also tells me that Robson was the first that brought into England the art of making Venice glasses, but Sir Edward Zouche (a courtier and drolling favourite of King James) oppressed this poor man Robson, and forc't it from him, by these four verses to

King James, which made his majestie laugh so that he was ready to bes- his briggs. The verses are these:

> Severn, Humber, Trent and Thames,
> And thy great Ocean and her streames
> Must putt downe Robson and his fires
> Or downe goes Zouche and his desires.

The King granted this ingeniose manufacture to Zouch, being tickled as aforesayd with these rythmes; and so poor Robson was oppressed and utterly undon, and came to that low degree of poverty that Mr Philips told me that he swept the yard at Whitehall. . . ."

Additional and some duplicated information on glassmaking is found in Chapter 25, Section X, by F. W. Gibbs of the Royal Institute of Chemistry, London.

The published index of British patents in the manufacture of glass lists eight for the period 1623-1699, four for 1700-1749, seven for 1750-1799, and 49 for 1800-1849 (most of them in the 1840's). These figures indicate that although Britain was the cradle of invention in the period covered by Volume V (1750-1850), changes in the glass industry were not violently revolutionary, at any rate not until the Excise Tax on glass was completely abolished in 1845. L. M. Angus-Butterworth, author of Chapter 12 (pp. 358-378), does well to concentrate on the various processes used in making lenses, tubing, rod, mirrors, and window glass rather than on domestic ware which, being eagerly sought by collectors, has always received a disproportionate amount of publicity. He also gives a useful section on colored glasses. Much of the detail in the chapter is to be found in *The Curiosities of Industry and Applied Sciences* by George Dodd (London, 1852), though this is not mentioned in the bibliography; other items which might have been noted are *The Plate-Glass-Book*, by a Glasshouse Clerk (London, 1771); *Treatise on the Origin, Progressive Improvement and Present State of the Manufacture of Porcelain and Glass*, by G. R. Porter (London); *The Crown Glass Cutter and Glazier's Manual*, by William Cooper (Edinburgh, 1835); and *Treatise on the Art of Glass Making*, by William Gillinder (Birmingham, 1851).

Enterprise and invention in glass manufacture were vigorously stimulated by the Great Exhibition of 1851, and the latter half of the nineteenth century (covered by Volume V) was a time of enormous technological advance. Despite this, only a dozen pages (ch. 28, pp. 671-682) are devoted to it under the heading "Glass Technology." The author, Professor R. W. Douglas, of Sheffield University, the Hon. Secretary of the Society of Glass Technology, is one of the foremost authorities on the scientific aspects of glass, and his article is a masterpiece of compression. As far as glass is concerned there is an element of arbitrariness in closing this *History* at 1900, for the main development

in automatic bottle blowing and the drawing of sheets from furnaces did not occur until the turn of the century. The introduction of the Siemens furnace meant a great improvement in the quality of lens glass, but although colored glasses of astonishing range were made for decorative ware, in the main the age-old processes of manufacture continued to operate, with trial-and-error experimentation rather than accurate scientific data being accepted as the basis of change. Much has been published on glassmaking in this final period, but it is cold comfort to note in the brief bibliography that most of the textbooks and literature in general about glass are by German authors.

In these anxious days of nuclear weapons, let the insatiable student of glass who demands more than these five volumes provide take consolation in the following extract from the "Observations on the Epistle to the Reader" in Merrett's edition of Neri's book "I have heard a singular artist (i. e., in glassmaking) merrily to this purpose say, that their possession would be the last in the world: for when God should consume with fire the Universe, that then all things therein would Vitrifie and turn to glass. . . ."

CHEMICAL TECHNOLOGY

MARTIN LEVEY and DENIS I. DUVEEN*

I

Th origin of chemical technology is associated with the procurement, use, and development of the food, clothing, and shelter of primitive man. By the time of the earliest historic period, toward the end of the fourth millennium B. C., many of the occupations involving chemical technology had already been well delineated. Included among the industries and professions were dyeing, tanning, perfumery, metallurgy, medicine including pharmacology, and the manufacture of pottery. In the first three chapters under review (Vol. I, chs. 11 and 21; Vol. II, ch. 2) Professor R. J. Forbes has given an

* Dr. Martin Levey, an authority on ancient chemistry and chemical technology, is with the School of Historical Studies of the Institute for Advanced Study: he is responsible for Part I of this review, dealing with the appropriate portions of Volumes I and II of *A History of Technology*. Mr. Duveen is the author of Part II, covering the last three volumes. President of the Duveen Soap Corporation, Mr. Duveen has long maintained a scholarly interest in the history of chemistry, assembling a large collection of alchemical and early chemical works (now at the University of Wisconsin) and possessing an extensive collection of the writings of Lavoisier. The American Chemical Society presented Mr. Duveen with the 1960 Dexter Award in the History of Chemistry.

excellent though tantalizingly brief account of some of the early developments in chemical technology. To these this reviewer would like to add a few notes.

The center of the wool trade and woolen cloth manufacture in the fourth and third millennia was in Sumer. (M. Levey, *Chemistry and Chemical Technology in Ancient Mesopotamia* [Amsterdam, 1959], pp. 101 ff.) Partly because of this, dyeing and tanning there reached a very high level of development. The Sumerians possessed not only substantive and vat dyes but also mordant dyes. Babylonian mordants, inherited from the Sumerians, included (1) metallic salts of aluminum and iron in the form of various earths and alums, and (2) tannins derived from a number of natural sources. The latter included gall nut, pomegranate rinds, acacia bark, and sumac. Auxiliaries such as slaked lime and carbonates have been discovered in dye plants of the first millennium B. C. in Palestine. The use of salt in "salting out" was known to Babylonian pharmacists and soapmakers. It it probable that salts were used in the case of soluble dyes to assist exhaustion of the dye baths when using direct dyestuffs.

The dyeing of wool prior to plucking or shearing was frequently practised as it is done today in the Near East. A Nuzi tablet of ca. 1300 B. C. mentions a "sheep whose red-dyed wool has been plucked." Almost always, where the wool was to be dyed, it was carried out on the yarn or thread. Because of the high cost of dyeing, the natural colors, white, black, gray, and brown, were the most common.

The evidence for the use of alum is to be found in early as well as in later cuneiform texts. In ancient Mesopotamia, alum was widely used in such diverse technologies as tanning, dyeing, glass-making, washing, medicine, and in cosmetics. Through the craftsmen of Babylonia, Palestine, and Egypt, the Arabs acquired a fund of practical knowledge on the use of alum in industry and medicine. (Cf. Ibn abī-al-Bayān [b. 1161], *Al-dustūr al-bīmāristānī, passim.* Text publ. in *Bull. de l'Inst. de l'Égypte*, XV [1933], 13-78; It is also frequent in Ibn Bādīs, *'Umdat al-kuttāb wa'uddat ḏawī'l albāb* of ca. 1035, Berlin MS Landsberg 637, and another bookbinding text in MS Chicago A 29809.) Alum was one of the most important chemicals employed in ancient Babylonian technology. This early extensive use of alum helps to explain its wide application in the later classical period.

The most important use of aromatics in early antiquity was not in cosmetics but in pharmacology. This is demonstrated in an old medical tablet of the end of the third millennium B. C. as well as in other texts. Long lists of aromatic botanicals are known from the early third millennium onward. Through a study of the aromatics in pharmacology and perfumery in the Sumerian and Akkadian texts, evidence may be provided to show the transmission paths of technology in these fields westward through the artisans and craftsmen.

It is of importance to the history of perfumery that distillatory

and extraction apparatus were already known in Tepe Gawra about 3600 B. C. It may be shown that the Alexandrian and Arabic stills are in the direct line of evolution of this prehistoric still apparatus. That chemical technology was associated with the ancient kitchen is now without doubt. An Akkadian text of ca. 1200 B. C. on the manufacture of perfumery products names two women as the operators.

The textual material on the refining of silver goes back to about 2000 B. C. Two steps were necessary in the Sumerian refining process: (1) smelting where most of the lead was oxidized and then almost entirely volatilized at a medium temperature, and (2) cupellation at a higher temperature. Because of the different degrees of heat required in the two processes, different furnaces were probably used, or the muffle and fire required major readjustments.

By the end of the fourth millennium B. C., the Mesopotamians had built furnaces capable of reaching a temperature of about 1100° C. This is sufficient for the smelting of copper and the manufacture of its alloy bronze. It was shortly after this that pottery kilns, judging by the artifacts, were so constructed that the flue gas produced a reducing atmosphere. This was necessary for reduction of some ores although the use of carbon for this purpose was known. The tablets show that tin was purposely added to copper to facilitate the casting process in the case of intricately designed objects. Chemical analysis bears this out. There is no proof that tin was introduced to increase hardness. Specimens studied show microstructures of cold working and annealing or of hot working subsequent to casting, aside from those specimens which contained significant amounts of tin. Thus, two conclusions may be drawn—that tin was not abundant, and also that the tin addition was known to assist in the casting of complicated objects.

Metallographic and chemical analyses clearly indicate that there was nothing accidental about the use of tin as some have supposed. It is certain that bronze came about as the result of empirical studies by the Mesopotamians. This is evident in both the results from the artifacts and the texts themselves.

In the chapter (Vol. II, ch. 10) on prescientific industrial chemistry by F. Sherwood Taylor and Charles Singer, no consideration is given to the elaborate industrial chemistry of early antiquity. A haphazard discussion of the literature on the sources of technical information is not very helpful. It is misleading in that the non-Latin sources are not described. This reviewer doubts the rash statement that alchemical experiments led to "a development of apparatus from which that of scientific chemistry was at long last evolved." There is evidence, on the other hand, that the importance of alchemy to the development of medieval chemistry has been highly overestimated and that the technological workers themselves have been given insufficient credit. It is also regrettable that the account on drugs is very inadequate since it

was in this field that early medieval chemical technology was brought to a high state of development.

Dr. E. J. Holmyard's article on alchemical equipment (Vol. II, ch. 21) contains much information and is well written. However, he neglects the changes brought about in apparatus by chemical industry over thousands of years prior to the alchemists. Certainly, the published (1948) ninth century work, *Kitāb kīmiyā' al-'itr wat-tas'īdāt*, attributed by Karl Garbers to al-Kindī (the authorship is doubtful), if properly taken into account, would have changed much of the story in this chapter. In the present state of our knowledge, it is not much more than an assumption that the alchemists made major contributions to the development of apparatus design. Had it not been for the glass-making improvements by industry, most of the alchemical apparatus would probably have resembled that of thousands of years earlier. It is questionable whether a full chapter on alchemical apparatus is deserving of a place in a short history of technology.

In the account of chemical technology, *A History of Technology* has a number of serious gaps. Further, some of the chapters in this field might well have been replaced by more appropriate material. A few of the chapters discussed, however, have a well balanced perspective and should lead to a greater interest in a field which has too long been neglected.

II

Volume III covers the sixteenth, seventeenth, and the first half of the eighteenth centuries and consists of over 700 pages of text. Of this bulk only 30 pages have been allocated to Chapter 25, "Invention in Chemical Industries," and it appears somewhat evident that Mr. F. W. Gibbs has found this limitation cramping in his attempt to cover the subject. Although the volume contains a substantial section, Chapter 2, on Metallurgy and Assaying (45 pages), more than ten per cent of the 30 pages are devoted to the manufacture of Tinplate and Zinc; similarly, notwithstanding the dedication of an earlier 17 pages, Chapter 3, to Coal Mining and Utilization, we find a further ten per cent of the chapter under review devoted to the use of coal as a Substitute for Wood.

The chapter opens with two general sections on the Development of Chemical Arts and Science and Industry, which provide a good enough introduction. Subsequent sections deal with "selected processes that best seem to characterize the period." Dyeing and Colouring is dealt with in three pages, and this important and extensive subject very obviously cannot be adequately surveyed, for the period in question, in so short an article. Varnishing, Japanning, and Lacquering provide the subject for the next article and are dealt with in sufficient detail. Glass Making then fills about three pages and this, too, is inadequate in volume. Soap making occupies the next two pages, and a final Con-

clusion closes the chapter. To sum up, one is left with the impression that Mr. Gibbs has done his best to cover an important and interesting field within a totally inadequate allocation of space. The Bibliography provided at the end of the chapter is meagre.

Volume IV is concerned with the Industrial Revolution and covers the years 1750-1850: Chapter 8 is called " The Chemical Industry " and consists of two parts. The first part is subtitled Developments in Chemical Theory and Practice and was contributed by the late Dr. E. J. Holmyard, who points out that it is a recognized fact that the scientific revolution of the seventeenth century hardly applied to Chemistry but that a great change came over the chemical scene in the second half of the eighteenth century. As is well known the pioneer experimental work of Black, Scheele, Priestley, and Cavendish allowed Lavosier to elaborate the modern explanations of combustion and, in turn, Lavoisier's work led John Dalton to his all-embracing Atomic Theory that made to-day's Chemistry and Physics possible. All these momentous developments occurred during the period in question and have been fully but succinctly expressed by Holmyard in a mere 14 pages. The reviewer feels that this part I of Chapter 8 is a model of concise, accurate, and simple exposition that might well serve historians and scientists as an example.

The only minor criticism that might justifiably be levelled at this article is the limited nature of the bibliography provided at the end.

The second part is subtitled Interaction with the Industrial Revolution and was written by A. and N. L. Clow. In their article the authors indicate, quite rightly, the fundamental role that chemistry has played in the development of almost every branch of technology and observe that this fact is often unnoticed because the chemical industry operates on a very wide range of materials and its products are but rarely ends in themselves. The social impact of various applications of chemistry to everyday life is mentioned and its part in ameliorating the lot of the people made apparent. In the 25 pages devoted to this section an account of the progress made in the following fields is sketched: alkali production, manufacture of glass, production of sulphuric acid—the kernel of the chemical industry—bleaching, dyeing, and soap-making. In addition to this, various other industrial developments such as the manufacture of matches, paper, and superphosphate fertilizers are mentioned. The section closes with an adequate bibliography and gives a fair but compressed view of the subject.

The last half of the nineteenth century is covered in Volume V, which brings the series to a close. Part IV of this volume, The Chemical Industry, occupies some 64 pages and is divided into four chapters. The first, ch. 11, is concerned with Heavy Chemicals and was written by Trevor I. Williams; it starts with an excellent description of the importance, development, and comparative efficiency of the Leblanc and Solvay processes for the manufacture of sodium carbonate. Caustic

soda production is slightly and that of sulphuric acid more extensively treated. An account of the earliest electrochemical processes—for the production of aluminum, caustic soda, and chlorine—is given, and the section closes with a description of developments in the manufactures of phosphorus and superphosphate. The section gives an adequate birdseye view of happenings in the basic heavy chemical industry.

The second chapter (ch. 12) deals with Dyestuffs and comes from the pen of the late Dr. E. J. Holmyard. Excellent historical accounts of the origins and uses of cochineal, madder, indigo, logwood, brazilwood, fustic, weld, saffron, safflower, and annatto are given. The birth and development of the aniline dye industry is described, and the importance to the dye industry of the discovery of the structure of the benzene molecule by Kelsule is explained. The classification of dyes and their subsidiary uses is also given. This is a well written and complete section.

J. McGrath contribues the third chapter (ch. 13) which is concerned with Explosives, whose industrial importance is not always realized. Gunpowder, nitroglycerine, guncotton, blasting explosives, propellants, picric acid, and detonating compounds are all treated historically and practically. A good coverage of the subject is provided.

The last chapter (ch. 14) is devoted to Fine Chemicals and was written by Arthur W. Slater, who starts off by pointing out that the distinction between fine and heavy chemicals is easy to recognize but difficult to define. The development of a fine chemical industry could only occur subsequent to the perfection of such equipment as filter-presses, centrifrugal machines, and distillation equipment. Reviews are given of the developments in the fermentation industries, destructive distillation of wood, manufacture of anaesthetics, antiseptics, disinfectants, essential oils, drugs, pharmaceuticals, bromine, iodine, boric acid, and borax.

The bibliographies to all four chapters appear to the present reviewer to be inadequate, but it is possible that they were limited by a general policy laid down by the editors.

FOOD TECHNOLOGY

WAYNE D. RASMUSSEN*

Food technology makes the raw products of farm, forest, stream, and sea useful as food for human beings. In many instances, without the application of technology, the raw product is useless as food, and

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may even be harmful if consumed in its natural state. In other instances, technological arts increase the value of the basic material as a food, making more nourishment available to the consumer. They also permit the preservation of food for future consumption, a primary requirement for the development of civilization. Finally, food technology may make the original product more appealing, either by a radical change in its nature or by a simple change which makes the food more appetizing. In another sense, food technology may include the processes whereby man obtains his food supply, although agriculture is excluded from the definition, at least for the purposes of this review.

As Daryll Forde points out in Chapter 8, Volume I, of *A History of Technology*, man has obtained his food during by far the greater part of his history solely by foraging, hunting, fishing, or trapping. Drawing upon the work and techniques of anthropology, Mr. Forde traces the development of foraging tools and techniques and of hunting and fishing devices. He then illustrates these developments by describing their use among primitive groups in various geographical environments of the present day. While the number of sources from which the author draws his illustrations are very limited and do not reflect much of the research of the past twenty years, Mr. Forde writes clearly and his conclusions are those generally accepted by students in the field.

The earliest development of the culinary arts is discussed by R. J. Forbes in Chapter 11, Volume I. As he points out, the kitchen gave rise to furnaces and ovens, apparatus for grinding and crushing, the use of alcoholic fermentation, methods of preservation, and the extraction of liquids by pressure from seeds and fruit.

Palaeolithic man began cooking food by the simple process of roasting. Boiling became possible after suitable receptacles were invented. Neolithic man needed improved means of cooking after he began to cultivate, dry, and grind cereals and to breed livestock. Boiling and baking and the preparation of alcoholic beverages developed during this period. Drying, salting, and smoking were used for preserving food for future use.

Early historic times saw the baking of loaves of bread, using fermentation, from cereals that had been crushed, ground, and sieved. In Egypt, several vegetables and fruits, as well as fats and oils, added variety to the diet, while Palestine was famous for its wine and oil. Several types of grinding devices had been introduced in Mesopotamia and Egypt by the beginning of historic times. Some of the grain, as well as fruits, went into the production of alcoholic beverages. Malting developed as a process for making cereals more palatable and was then adapted to brewing. Fermentation was adapted to baking, and leavened bread, cakes, and biscuits made the consumption of cereals more attractive.

Forbes continues his discussion of food and drink in Chapter 4,

Volume II, where he points out that the production of flour, olive-oil, wine, and beer, the four mass-produced aliments of antiquity, required forms of crushing or disintegrating apparatus. Wheat was first extracted from the ears by threshing and winnowing, then was dehusked by pounding, and was finally ground into flour. Preparing malt for beer required a similar process. The fruit of the olive had first to be bruised, by pounding or some other process, and then pressed to extract the oil. Grapes were also pressed to obtain their juice. Much of the chapter is devoted to the techniques developed for carrying out these processes and to the making of wine, cider, beer, and spirits.

Contrary to the impression given by poems and legends, grain products and vegetables were the main foods of both Greeks and Romans. Only the rich ate meat, and even for them supplies were limited. During the medieval period, much the same situation prevailed. The diet of the masses was mainly vegetarian and frugal, two meals being usual. Complaints were voiced that the peasants, who produced the food, had the sparsest diets. There is a great deal of source and secondary material on these periods, and the author makes good use of it.

The story of food and drink is continued in Chapter 1, Volume III, by the same author, R. J. Forbes. Discovery of the New World and direct contact with the Indies and the Far East brought a new range of food plants and animals to European knowledge. The most important food crops were potato, maize, rice, oilseed, and sugar-cane. According to the author, the potato was the most important addition to European farming and diets. Tea, coffee, and cocoa contributed variety. Tobacco came from the New World, and its introduction was marked by almost as much controversy in the 1600's as its continued use is today.

There was little change in the manufacture of alcoholic drinks during this period from the Renaissance to the Industrial Revolution, although drunkenness became a social evil with the greater availability of spirits. Milling was a major industry, using most of the available waterwheels and windmills. The machinery used was simple but efficient. More food appears to have become available, and people ate more meals, adopting spoons, forks, and tableware. Ingenious spits made the work of roasting easier and more effective. No new techniques were devised for preserving food, and the ancient techniques of salting, drying, and smoking were but little changed. Modern ideas on food and diet were just beginning to emerge at the close of this period. The references and bibliography for this chapter are an unusual mixture of reports of recent outstanding research in the subject matter, outdated material, and volumes for popular consumption based upon little research or even knowledge.

The Industrial Revolution brought certain specialized developments in food technology. In Chapter 2, Volume IV, C. L. Cutting presents

an excellent short essay on fish preservation, pointing out that fishing, including whaling, is the last survivor of the food-gathering stage of any economic importance. Fish is rapidly affected by microbial spoilage and has thus needed special treatment to preserve surpluses. Herring was being salted on a large scale by the twelfth century and smoked by the thirteenth. Since that time, much effort has been devoted to improving these basic techniques and to insuring a standard product. Cod is basically preserved by salting. In the last two centuries, a considerable industry developed in the North Sea of keeping sea-fish alive until they were sold. About the same time, ice was first used for preserving fish while it was being transported. While more ample supplies became available, ice was usually used only for the more valuable species of fish.

During the nineteenth century, the standard of living generally rose, and the diet became more varied and more healthful than in the past in most of Europe, according to G. E. Fussell, in Chapter 1, Volume V. Mr. Fussell, one of England's outstanding agricultural historians, ascribes this progress to growth of industrial production, development of better methods of transportation which enabled surplus foods from remote parts of the world to be brought to Europe, an enormous increase in the area of land farmed by Europeans overseas, and the increased productivity of European agriculture. The author then develops these themes in terms of changes in agricultural production in the major areas of the world.

Food technology, as distinct from farm production, is discussed for the same period by T. N. Morris in Chapter 2, Volume V. As he points out, the Industrial Revolution made it necessary for mankind to give greater attention to the task of preparing and preserving food. This development has meant that a smaller proportion of the population has had direct access to the land and the means of providing themselves with food, yet the total number of mouths to be fed has increased. Thus, in many ways, the middle of the nineteenth century marked a definite break in the development of food technology.

Scientific knowledge by 1850 was at a point where major improvements in traditional processes and the development of the modern processes of canning, refrigeration, dehydration under scientifically controlled conditions, and preservation by toxic chemicals were possible.

Milling changed with the introduction of roller-milling and the virtual disappearance of stone-milling. Roller-milling made the production of fine white flour, devoid of bran, wheat-oil, and vitamin B, possible. Baking operations were mechanized.

The salt-curing and smoking of meat, particularly bacon, changed from dry-salting to tank-curing. Refrigeration made it possible to carry out these operations throughout the year. Dairying underwent major changes with the invention of the centrifugal cream separator

in 1877, the introduction of a simple test for determining the amount of butterfat in milk, and the application of temperature and chemical controls to the making of butter and cheese. Evaporated, condensed, and dried milk all came on the market after 1850.

Modern processes of food preservation, according to Mr. Morris, have contributed far more than the older ones to the development of modern ways of life and of waging war. Canning has been one such process. It became possible to control the process scientifically after Pasteur's work in 1861, but it was not until after the turn of the century that canning was governed by scientific rather than empirical rules.

Machinery for making ice and producing cold has brought about major changes in diet and availability of food supplies. In the 1870's, chilled and frozen meat was shipped successfully from the United States, Argentina, and Australia to England and the continent. Since then, many changes and improvements have made these techniques of major importance in many aspects of food procurement and preservation.

In speaking of dehydrated foods, the author states that in nutritive value, flavor, and appearance when prepared for the table, they can now take their place beside canned and frozen foods. Many readers, judging from personal experiences during World War II, may quarrel with this statement, even though dehydrated foods have obvious uses.

The brief discussion of chemical preservatives, written from a British viewpoint, should be most instructive to American students. Since such preservatives are harmful to human consumers, they have been disallowed.

Generally, the six chapters and part of a seventh devoted to food technology in these volumes present a clear, useful picture of major developments. The references and bibliographies are inadequate, but are perhaps as much as one might hope for in a comprehensive history. Does this mean, then, that there is little left of basic importance for investigation? By no means. Recent studies have cast new light upon old topics and have opened new topics for investigation. The excavations and dating of material at Jarmo in Iraq may well require reconsideration of the development of the earliest aspects of food technology. Other disciplines, too, are adding to our knowledge. For example, the work of Hugh C. Cutler and other ethnobotanists may well require revisions of current ideas about food origins.

The entire area of diet has been so little studied that aspects of it are entirely open for investigation. Such work can be rewarding. For example, the first review of American food habits, *The American and His Food; A History of Food Habits in the United States*, by Richard O. Cummings, appeared in 1940 and had a definite influence upon governmental food policy during World War II. The United States Department of Agriculture has been developing statistical data on the

American diet, and some similar work has been done in England. Has diet changed because of food technology or have dietary changes brought forth developments in food technology?

Classicists have contributed much to the area under review. However, some of their work seems pedantic and disputatious, considering the areas still untouched in ancient times. In whatever age or speciality one's interest may lie, the food historian must urge that attention be given to subjects still little known rather than to reworking a few obvious or popular topics.

Applying this criterion to the most recent period covered by the Singer volumes, one may conclude that distilling and milling have been adequately reviewed by Forbes and by Storck and Teague, respectively. Dairying has been covered in part by a number of studies, yet an overall review of technological change in the industry would be useful. A definitive history of canning is yet to appear, and now would be an appropriate time to review what appears to be a declining industry. The excellent work on mechanical refrigeration by Oscar Anderson should not obscure the fact that the frozen food industry, which now claims a history of over 25 years, is virtually untouched by the scholar. The dehydration of food under modern conditions is also awaiting investigation by the student of technology. The use of chemical preservatives and the related problem of the appearance of other chemicals in food products is so controversial a subject in the United States, if not in Great Britain, that only a scholar of rare courage should undertake to study the problem. A beginning has been made by Oscar Anderson in his *The Health of a Nation.*

In summary, opportunities for basic research in food technology seem almost unlimited. And what aspect of technology is more basic to man's existence than the food he eats?

AGRICULTURAL MACHINERY

REYNOLD MILLARD WIK*

"Man does not live by bread alone," but neither can he live without it. In this sense, the story of agrarian enterprise is one of the epics of history because the survival of the human race depends on food. As the world's oldest industry, agriculture has been exalted. George

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Washington called it the noblest profession, and Daniel Webster claimed it required more talent to be a good farmer than a good statesman.[1] Francis Bacon exclaimed, "We may still talk what we please of Lillies and Lions Rampant . . . but if Heraldry were guided by reason, a Plough in a field arable would be the most noble and ancient Armes."[2] Today, scholars recognize the agricultural revolution as a twin brother of the Industrial Revolution. In fact, Henry A. Wallace as Secretary of Agriculture insisted that over the centuries agriculture had increased much more in efficiency than industry.[3]

Although this recognition is commendable, most historians tend to slight the technology of farm machines—the iron and steel which made obsolete the "Man with the Hoe" and gave rural people a chance at the luxuries associated with urbanization.[4] The editors of the Singer volumes are also vunerable at this point, for apparently they had only a mild interest in the technology of agricultural implements. Hence in the last three volumes they allocated only twenty pages to the entire account of the evolution of farm machinery over the 400-year span from 1500 to 1900. Furthermore, the era 1850 to 1900, one of the most dynamic and creative periods in modern agriculture, is reduced to two pages. Naturally such limitations prove disappointing and deadly. It is a bit difficult to explain agrarian technology in words that could be inscribed on the head of a pin.

As a result, Volume V disregards farm machinery used in Holland, Germany, Italy, Russia, Scandanavia, Australia, New Zealand, Canada, and the South American countries. In the United States, there is mention of the McCormick and Hussey reapers and the Jefferson, Wood, and Deere plows, but these are not described nor their significance noted. Reference is made to the expansion of agriculture into the Trans-Mississippi West and into the western Canadian provinces, but again there is no discussion of the machines which made possible the doubling of American farm acres in a thirty-year period following the Civil War.

Another questionable editorial decision concerns the definition of "technology." When the word is made to include "how things are done or made," the door is opened to embrace virtually all activities of mankind. Such scope is ambitious, but it creates frustrations for the reader. The diversity of subject matter results in the fragmentation of information, encouraging schizophrenia rather than coherence. This tendency appears in R. J. Forbes' chapter on "Food and Drink" (Vol. III) and G. E. Fussell's articles on techniques of farming and food production (Vols. IV and V). In a total of eighty pages comments are made about horticulture, agronomy, viticulture, arborculture, animal husbandry, and the farming practices in Great Britain, the Continent, and the New World. Items range from the origin of potatoes, maize, tea, coffee, tobacco, rice, hemp, sugar cane, buckwheat, and indigo to the production of bananas in the tropics and the citronella of

Ceylon. Topics include the influence of wars on agriculture, animal breeding, the impact on the Italian farmer of the Risorgimento, and the conservation of manure. Attention is focused upon the work of agricultural societies and to the scientific work of prominent leaders such as Louis Pasteur and Arthur Young as well as the efforts of less well-known figures, as the Duke of Bedford and Von Petkus. The dietetic sciences cover the chemical and physiological evolution of food, cook books, eating habits in the Middle Ages, the distillation of alcoholic beverages, and digestion within the stomach.

Such a mountain of information crowded into limited space becomes encyclopedic and, at times, a jumbled hodge-podge of miscellanea. The compilation fails to meet the original purpose of the editors—to write a history of technology with appeal for the general reader. This text-book filled with fragments of information may not materially facilitate the broadening of the cultural horizons of specialists. Perhaps the editors lost sight of the intended reading audience. If written for science students as collateral reading, the articles on agriculture are too factual; if intended for researchers, they are too brief and incomplete. Thus it is likely that neither the specialist nor the general reader will be fully satisfied.

Another serious indictment of this work lies in its absence of continuity. There is an evolution of machinery from the simple to the complex, somewhat similar to the Darwinian evolution of animate life. Interest centers in the evolutionary mechanical jumps discovered by perceptive men eager to reduce the amount of manual labor on the farm. These technical discoveries sometimes occur when necessity is the mother of invention, and at times when curiosity or mere chance becomes the father of invention. Occasionally farmers adopt new machines readily, while again they may resist change for a century. Yet in this technological progression there is a continuum, a sequence of events which makes the history of technology hang together like strands in a rope. As in a successful novel, the thrill comes in experiencing a series of events. This sense of movement is not too evident in the Singer volumes.

For example, the most basic processes in the production of grain crops are the preparation of the soil, planting the seed, harvesting the crop, and threshing the grain. As centuries passed, improvements in farm machines occurred in each of these four steps of farm work. This is a natural organization of rural technology which makes sense to the reader, and when this formula is followed, as in Volume IV, the results are most gratifying. Here the chapter on "Agriculture: Farm Implements," by Olga Beamont and J. W. Y. Higgs is excellent. In text and illustration are the Rotherham and Ransome plows, the Jethro Tull and Garrett, Smyth, and Hornsby grain drills, the Patrick Bell and Cyrus McCormick reapers and the Michael Menzies and Andred Meikle threshing machines.

After following a logical pattern of organization for the period 1750 to 1850, one would expect the account to be brought up to the twentieth century in Volume V. Unfortunately, and for strange reasons, the four basic farm procedures with their appropriate machines are discarded in favor of such topics as general farm practices and the types of food raised in different regions. Thus the reader attempting to follow the history of agricultural machinery is left stranded. Like the stopping of a theater production in the middle of the play, the audience is left to speculate on the probable outcome of the story.

Furthermore, the history of rural technology demonstrates that tools and mechanical equipment are dependent upon an adequate source of power. Machines cannot work without some force of energy to operate, draw, or propel them. During the last two centuries, agriculture has moved through a three-phase power cycle. Initially, farm work was performed manually, in the tradition of Edwin Markham's poem. Later, much of this hand labor shifted to animals. When animal power proved inadequate, work shifted from animals to machines such as steam engines, electric motors, and gasoline tractors. Thus better means of power accompanied the invention of new farm machinery.

The drama here centers in the discovery of new power resources to break a series of production bottlenecks. The first power crisis necessitated the invention of plows which could harness animal power to prepare the seed bed; now men could plow more acres than they could harvest in a season. The advent of the horse-drawn reaper permitted farmers to harvest as much grain as they could plant; now they could raise more grain than they could thresh in the winter months. When horsepower machines failed to provide adequate belt power for threshing, the steam engine became essential for belt work. In this sense, machines plus adequate power created the agricultural revolution of the nineteenth century.

This marriage of power and farm machines appears only incidentally in the Singer volumes. The writers neglect to explain why new farm implements were so desperately needed. In fact, there is no mention of horsepower machines which provided all the rotary power on the farm before the introduction of steam engines, stationary gasoline engines, and the tractor. Horsepower machines were either treadmills or sweep-powers. Treadmills carried two or three horses which turned a revolving inclined platform. Sweep-power machines accommodated four to seven teams of horses hitched to sweep poles; traveling in a circle like a ship's capstan, they transmitted power through a set of gears which in turn applied the rotary power to any machine requiring belt power.

Likewise, the writers overlook the importance of the early stationary steam engines which furnished belt power for farm purposes. The advancement from horse power to mechanical power is one of the

major achievements in the history of modern agriculture. However, this constitutes a blind spot for historians of technology. They describe the use of steam engines in steamboats, railroad locomotives, and in industry, but neglect to observe that they were also used on farms. It is interesting to note that farm steam engines arrived on numerous farms in England and America before George Stephenson demonstrated the practicality of his "Rocket" iron horse on the Liverpool-Manchester railway in 1829. As early as 1812 Richard Trevithick built a four-horsepower agricultural engine for Sir Christopher Hawkins of Thevithan who used it for threshing, grinding corn, and sawing wood.[5] In the United States the "Stourbridge Lion" locomotive made its first successful run in 1829, and in the following year Peter Cooper's "Tom Thumb" gained fame on the Baltimore and Ohio railroad. Yet, from 1807 to 1812, stationary steam engines were installed on plantations in the United States and in the West Indies for driving sugar mills, saw mills, and grist mills. By 1838 there were 585 of these engines in the Southern states employed for belt work on plantations.[6]

This failure to see the application of steam power to agriculture has led to certain distortions of history. For instance, the impression remains that all planters in the South relied on cheap slave labor and shunned technological progress. Usually the planter is pictured sitting in the shade of his white mansion reading Walter Scott and drinking mint julep, while all slaves, in the image of *Uncle Tom's Cabin*, bend under the lash in the cotton fields. Plantation owners favored slave labor, but it should be remembered that they were among the most mechanically-minded people in the country. Frederick Law Olmsted described them as the "most intelligent, enterprising and wealthy men of business in the United States."[7] When water, wind, and mule power proved inadequate, they purchased 16-horsepower engines which cost $7000 each. Bolted down to foundations and belted to line shafts, they drove cotton gins, sugar cane mills, and threshing machines. Chimneys as high as fifty feet provided draft for the fireboxes where wood, coal, or dried bagasse were used for fuel. Eager to learn more about mechanization, these pioneers introduced power farming to America, a move destined eventually to remove the back-breaking labor of farm workers in both North and South.

Since the authors are British, they tend to emphasize the technology of their country. The material is illuminating but the focus too provincial; Britain made substantial contributions to agricultural "know-how" but had no monopoly on mechanical genius. Limiting the point of view to Britain means that much of the ingenious work of farmers and entrepreneurs in other parts of the Western world is ignored. For example, page 12 of Volume IV contains the statement: "Credit for most of the inventions made before 1850 must be given to Britain, but after 1850 America and the countries of the British

Empire began to play an increasingly important part." This is a generous gesture, my only complaint being that the writers never got around to the discussion of these non-British inventions.

Without the total picture, certain false impressions are given. Thus when the first English threshing machine which combined threshing with the cleaning of the grain was built in Thetford in Norfolk, in 1848, the reader assumes that this marked the invention of the first successful threshing machine. Yet the Pitts Brothers, Hiram and John, of Winthrop, Maine accomplished this feat in 1834, fourteen years earlier.[8]

Nor is mention made of American innovations such as the Moore-Hascall combines which were cutting 25 acres of wheat daily in Michigan in 1841.[9] (Combines were introduced in Britain in 1928.) Other significant American inventions were the Jackson automatic self-feeder attachments for threshing machines in 1870 and the Buchanan wind stacker of 1892—two mechanical devices which reduced the amount of labor in threshing by 50 per cent. The first successful string-tying grain binders manufactured in the United States in 1879 were later sold in England.[10]

The Singer contributors also neglect to show how agricultural machines in different countries were designed to meet local conditions. British farmers worked small farms extensively, had access to an adequate labor supply, and held conservative attitudes in farming practice. They desired machines built for durability and long life rather than for speed of operation. On the other hand, Americans opening up the vast prairies on the western frontiers, where land was cheap and labor often scarce or expensive, demanded machines of gigantic size and capacity. In the Sacramento valley of California Dr. Hugh J. Glenn used a threshing machine which was 35 feet long. When belted to an Enright steam engine it threshed 6,000 bushels of wheat in one day in 1879—a world's record for that time.[11] In the 1890's, the Best and Holt steam traction engines in the Pacific Coast states were leviathans with drive wheels twelve feet in diameter. These $6000 behemoths plowed 45 acres a day or combined 100 acres of wheat daily and were perhaps the most awe-inspiring machines used in agriculture. Thomas Campbell of Hardin, Montana in 1917 used fifteen Twin City tractors to plow 640 acres in one day, another world's record.[12]

To present a more balanced account of rural technology, the Singer staff could have profited by a more careful study of the American literature, such as Leo Rogin's *Introduction of Farm Machinery in its Relation to the Productivity of Labor in Agriculture of the United States during the 19th Century* (Berkeley, 1931); Fred Shannon's *The Farmer's Last Frontier* (New York, 1934); William T. Hutchinson's *Cyrus Hall McCormick* (New York, 1930); Lewis C. Gray's *History of Agriculture in the Southern United States to 1860* (New York, 1930); R. L. Ardry's *American Agricultural Implements* (Chicago,

1894); *Reports of the United States Commissioners to the Paris Universal Exhibition, 1878.* (Washington D. C., 1878). A perusal of these accounts would have eliminated such errors as stating that the Canadians in the Western provinces did winter plowing, in a region where the soil is often frozen five feet deep at that time of year.

Fortunately, the volumes contain good illustrative material, a necessity for an adequate presentation of technology. The pictures are sharp and timely but often inserted into the text at random. A good shot of a British portable steam engine follows a description of Merino sheep in France, but the odd arrangement is not a serious matter. Frequently machines appear without the name of the manufacturer, but sources are cited enabling the reader to trace this information.

As one puts down this work and thinks about the chapters on agriculture it appears that a history of its technology creates special problems for writers and editors. A baffling dilemma persists. Obviously such a broad field defies the single scholar, so experts in specialized fields must contribute their views. But these concentrated studies must be translated into a broad synthesis to give the general reader the total scene, and it is difficult to find a specialist who can do both. Thus Geraint Jenkins can write a brillant section about early carts and wagons in Britain (Vol. III, pp. 139-150), but who can do justice to the whole topic of rural transport in the same era?

Another vexation lies in the obscurity of the evidence. The student wants to know the "firsts" of technology, yet writers, aware of the mercurial nature of the evidence, hesitate to indicate the first inventions. Aware that they may be proved wrong, they get "gun shy" and, attempting to avoid misstatements, they drift off into qualifying phrases, generalizations, and vagueness, all of which suggests shallow research. Perhaps the only consolation is to be found in the idea that all knowledge is in flux and that scholarship implies only a quest for better answers, not that they can be nailed down permanently.

Writers of technology face another question: Can they write about machines with some life and spirit, or must descriptions of machinery be lifeless and sterile? The agricultural historian might well consider people as well as gadgets. In the Singer chapters the reader sees little of the individuals who invented mechanical contraptions, those men who defied convention and broke down barriers of ignorance. In addition, there were the people who protested the innovations, those who adopted the new techniques, and those who experienced a thrill in facing the challenge of the ever-changing course of mechanization.

In this respect, one might cite the farm engineer as one example of a class of workmen who have been consistently overlooked as a source of hero worship. In contrast natty steamboat captains and railroad engineers with red handkerchiefs tied around their necks are immortal. Casey Jones in his old "Cannonball" or Jim Bludsoe on the ill-fated "Prairie Belle" are glamorized, but scarcely a word of recog-

nition befalls the host of farm engineers who brought power farming to rural areas. Here were hard working men, tough, resourceful, and practical, who in greasy overalls coaxed their rusty engines around straw piles or sighted their puffing dreadnaughts down the long furrows on the plains. These sons of the sod with their red necks, pitch forks, and corn cob pipes might appear to be simple plodders far behind the times, yet as mechanical pioneers they were often ahead of their times. Long before the appearance of tractors or automobiles and while the wealthy aristocrat in the city was still confined to the horse and buggy, the common farm engineer was chuffing across the fields and roads of the countryside in a private, self-propelled machine.

Again in retrospect, the Singer *History of Technology* is an honest effort to enlighten the reader. If weaknesses appear the editors might take satisfaction in the reply of railroad magnates when red-eyed Populists criticized their policies in the 1890's. "Well, if you don't like the way we run this railroad, go and build one for yourself." This notion will restrain the most violent critics.

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[5] Francis Trevithick, *Life of Richard Trevithick* (London, 1872), p. 38.

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METALLURGY

CARLO PANSERI*

The history of the beginnings and development of metallurgy forms the subject of the first four chapters of part V of Volume I of *A History of Technology*. These were written by C. N. Bromehead (Mining and Quarrying), R. J. Forbes (Extracting, Smelting and Alloying), H. Coghlan (Metal Implements and Weapons), and H. Maryon (Fine Metal-Work).

The first metal utilized by man after gold was undoubtedly natural copper, but civilization was still oriented towards the use of lithic tools, so that scarcity of natural copper prevented it from exercising that decisive influence which began with the discovery of reduction methods for cupriferous ores and, later, of tin alloying methods.

Most probably the use of copper dates back to between the fourth and third millennia B. C., for the technology of this metal was sufficiently developed by 3000 B. C., and copper was already known and utilized in Egypt during the third Dynasty (about 2600 B. C.). In Europe, the first copper ore center was apparently situated in the Tyrol: the mines of Metterberg appear to have been exploited from 1600 B. C. until the Hallstatt period, viz., for about 800 years.

In the comprehensive synopses of Bromehead and Forbes, the reader is presented as wide a panorama as can be depicted by the present knowledge of the subject—and the view is the more impressive the farther the historical horizon is from us.

The first center of ancient metallurgical technology is placed by Forbes somewhere in the mountain range stretching from the Taurus to the Caspian Sea, and as far as present Armenia. This hypothesis is supported by two considerations: the local presence of ores and the abundance of fuel sources. Besides these, there are other secondary, but no less important, arguments of historical character and of formal derivation which make consistent this hypothesis of the original center.

But it must not be thought that the process of diffusion of metallurgical technologies from a primary center was quick and immediate. Centuries and millennia were to pass before the elaborate techniques of copper first, and of iron afterwards, reached the Greek peninsula, Italy, and the Iberian peninsula, or moved up the Balkan peninsula to the upper Danube and the eastern Alps. Along the way natural obstacles and the hostility of less developed peoples may have caused prolonged local arrests, during which particular technologies were

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evolved, and which acted in turn as secondary centers of successive diffusion of metallurgical techniques. The same process, of course, applies to all known metallurgies practiced in ancient times. Nevertheless, the fundamental differences between the metallurgical technology of copper and bronze and that of iron is not sufficiently emphasized by Bromehead and Forbes.

Actually, the transition from the preeminently smelting technology of copper and its alloys to that exclusively based on iron forging methods required the development of completely new knowledge and of specialized and complicated techniques which bear no comparison to the relatively simple metallurgy of the Bronze Age. When the Greeks denoted iron as "polikmetos" (difficult, fatiguing), they were probably not referring to its *extractive metallurgy*, which is not substantially more complex than that of copper, considering the richness of ores and the purity of fuels (coal, wood) employed in ancient times; rather they expressed the fact that pure iron, unlike bronze, cannot be put straightforwardly to practical use after smelting because it requires such further skillful and *fatiguing* work as hot forging, an operation such as carburization—not intuitive at all—in order to reduce it to its most useful form of steel, and, finally, in the case of higher metalurgical civilizations, an elaborate composition of layers of more or less carburized steels submitted to particular—and mostly localized—hardening treatments.

Although we are still lacking a general synthesis of the most recent metallurgical research on the structure of ancient iron products, the specialized studies along these lines have already demonstrated that progress in metallurgy can be traced much more efficiently by this method than by research based exclusively on the extractive and primary metallurgy of iron; indeed, the latter does not really show a wide range of varieties and is inadequate to characterize the very different levels of improvement. These are best evidenced by the so-called "anatomical studies" of tools and, above all, of arms, to the manufacture of which the most diligent attention was dedicated at all times.

In the Classical world and during the Middle Ages, metals—iron, bronze, copper, lead, or whatever it might be—had always been considered extremely precious, both as the product of hard and difficult work and as the fruit of complicated and adventurous crafts. So precious indeed and so infrequently employed that Pliny tells us that the gilded metal tiles on Agrippa's Pantheon, as well as its columns with capitals of Syracusan bronze, were a source of marvel for foreigners and of civic pride for the citizens.

The whole ancient world, and even the Renaissance, was, as Forbes justly says, much less dependent on metallurgy than subsequent centuries, not to speak of the present one which owes its more significant and spectacular accomplishments to the unprecedented development of

already known metals and those more recently put to use, such as aluminum, zinc, and magnesium.

It is scarcely surprising that in the ancient world the production of metal alloys was covered by a veil of mystery and legend, since techniques were almost wholly empirical and the physical-chemical laws of metallurgy were utterly ignored. In his prolix listing of famous bronzes, which occupies a great part of the 34th book of his *Natural History*, Pliny shows only a very limited knowledge of their production techniques; his evaluation was based chiefly on richness of color and opulency of patinae. A typical example is his description of the fabulous Corinthian Bronze, which was said to be the accidental result of a mixture of molten copper, gold, and silver which occurred during the fire following the conquest and sack of the town by consul L. Mummio in the third year of the 158th Olympiad (608 years after the foundation of Rome).

However, Pliny admitted that Greek craftsmen were acquainted with various kinds of Corinthian bronzes: a white one, similar to silver; a fawn-colored one (*auri fulva natura*), like gold; and a third which was said to be composed of equal parts of copper, silver, and gold. Among these bronzes, most precious of all was the famous *hepatizon*, of a rich and warm shade of liver, whose composition (*quamquam hominis manu temperatur*) was kept a secret by its makers. Connoisseurs were so keen on it that triumvir Antonio, with the complicity of Cicero, was suspected of proscribing Varro for refusing to give him his collection of Corinthian bronzes.

Quite a different trend was followed, as said before, by the metallurgical technology of iron and steel, which began in Europe about 800 B.C. in Noricum, and almost at the same time in Etruria, in the Celtic countries, and in Spain, with a tendency for the developments to differ in the different localities.

With his usual abundance of historical documentation, Forbes puts the old hypothesis according to which the different properties and qualities of steels known to the Greeks and Romans originated from the peculiar composition and purity of the different ores. Certainly their lack of precise knowledge about the slag-forming action of some mineral substances led naturally to a final product whose quality was determined by the richness and purity of the iron ore used; this explains why most celebrated products come from some favored regions, like Noricum, where use was made of spathic iron (iron carbonate), one of the richest and purest iron ores.

Recent research, however, has led us to consider as more and more probable another hypothesis: while availability of good iron ores must certainly have been the decisive factor in starting a flourishing metallurgical industry, the quality of the final products (arms, tools) was determined by the gradual improvement of secondary technologies,

favored by such specialization as would be conceivable only in surroundings naturally prepared and economically oriented.

It is not at all proved, for example, that the famous Damascus steel or the poulad-jauharder of the Persians derived their exceptional properties from the quality of ores employed. On the contrary, they owe their characteristics exclusively to a special manufacturing process —carburization pushed to a pasty state in the crucible, followed by slow cooling. Forbes' statement (cf. Vol. II, p. 57)that "the blades (of 'damsk') were *quenched* and drawn to the desired hardness . . ." seems hardly acceptable.

The structure of poulad-jauherder (which means literally "wavy steel") is that of an hypereutectoid steel (C = 1.6-1.7%), heterogenized first by slow cooling of a small ingot, so that cementite (Fe_3C) could separate in needlelike crystals from the bottom die, plastified then by spheroidization of carbides through a more or less numerous series of "reheatings" and progressively increasing deformations induced by hammering. Such deformations were limited and very delicate at the beginning; afterwards, while plastification progressed, they became more and more powerful and deep. In that way, the small original ingot, which Tavernier says had the dimensions of the "*pains d'un sou*" and which Chardin describes as a "*pain rond comme le creux de la main*," was directly drawn and flattened roughly to the shape of the blade. Contrary to common opinion, the latter was not submitted to a real quenching process but only to a sort of normalization by twirling it in the air when still red from the last reheating or, at the most, by wrapping it in damp rags.

On the other hand, all other blades manufactured by completely different groups which were not in direct communication with each other, such as the Japanese, were produced by soldering or hot "boiling" techniques ("soldered damask"). Naturally from one piece to another, from place to place, and from one artisan to another, the choice and quality of steel, the perfection of welds, and above all, the final structure in terms of the complication of foldings and, consequently, the number and disposition of alternate layers of different steels differed from each other.

It should be noted here that the "soldered damask" technique was employed without substantial modifications throughout the Middle Age and even up to the beginning of the twentieth century. The French term "*étoffe*," defined by Larousse as "*barre forgée avec plaques alternées de fer et d'acier*," was still employed in the eighteenth century, as was the equivalent Italian term "*stoffa*," defined by the Tramater dictionary as a "*composizione d'acciaio e ferri diversi, che si riduce in massello col bollirla*" (composition of steel and different irons made into an ingot by boiling).

A similar technique was used in Val Trompia (Brescia) in the seventeenth century and later for the manufacture of the famous

"lazzarine barrels" (from Lazzarino Cominazzo, famous armorer, presumed to be their originator) and the more recent (eighteenth and nineteenth centuries) "Damascus barrels," whose fame was established by English and Belgian armorers. Curiously enough, the iron used for these gun-barrels was generally obtained from old horseshoe nails, these being considered the best material. Several grades of steel were often mixed with the iron, and here again each maker had his own ideas. In the nineteenth century the barrel-makers spared no efforts to produce beautifully marked barrels by exploiting the pattern of soldered damaskus, which when treated with acid brought out designs of great beauty and variety.

The chapter on "Metallurgy and Assaying" by Cyril Stanley Smith and R. J. Forbes in Volume III (Ch. 2) is valuable not only because of its completeness and profundity, but also for its rich and complete bibliography of 65 items.

Volume IV of *A History of Technology* introduces us to the Industrial Revolution and covers a period of exceptional importance for the development of our contemporary culture. It is in this period that science begins to be understood as objective research into causes and effects; that production processes begin to get free from subservience to an artisan tradition whose zealous maintenance and defense had doomed them to immutability; where the experimental method, some glimpses of which had been caught during the Renaissance by a few enlightened minds, gains force and tranforms the isolated thinker into a scientist who is aware of the external world of labor, production, and economy.

Whatever importance may be attached to the conquest of the new source of energy, manifested by the steam-engine, it is certain that not from this, or not only from this, arose that great movement which, because of its profound impact, came to be termed an industrial "revolution." This movement was due rather to the formation of an open mind to the idea of progress itself; to the fracture—sometimes slow and gradual, sometimes explosively violent—of the rigid framework of medieval conceptions. In this sense the work of the French encyclopedists in its strictly technological and scientific aspects, as distinct from the philosophical one, was defined as a most perfect war machine for breaching the bastions of the feudal mentality.

As in preceding historical eras, advances in metallurgy deeply influenced the development of all other technologies in this more recent period. These advances are related and documented in Volume IV by J. A. S. Ritson (Ch. 3, "Metal and Coal Mining—1750-1875)," H. R. Schubert (Ch. 4, pt. I, "Extraction and Production of Metals: Iron and Steel"), and F. W. Gibbs (Ch. 4, Pt. II, "Extraction and Production of Metals: Non-Ferrous Metals").

Much of the information contained in these chapters and in those in the fifth and last volume formed part of undergraduate and graduate

training in metallurgy only a few years ago. Thus the chapter by H. R. Schubert (Ch. 3, "The Steel Industry"), and those by R. Chadwick (Ch. 4 "New Extraction Processes for Metals," and Ch. 25, "The Working of Metals") are almost more of a chronicle than history.

Is it possible to draw any conclusions from such a brief examination of such a monumental work? Certainly the general reader, curious to know the steps of that long and hard march which has led mankind from caverns to metropolises and from the flint-stone axe to electronic computers, cannot close these volumes without a feeling of gratitude to those who conceived the idea and possessed the perseverance to compile and to publish it.

The specialist, and especially persons devoted to the history of metallurgy, may perhaps feel that the fundamental role of metallurgies in the development of successive cultures, and in particular in that period immediately preceding our own time, has not been given its due. This remark, however well founded it may be, is put forward with some hesitation, convinced as we are that every specialist could probably say the same of those parts concerning his particular field of interest.

In large general works on political history, the citizens of different nations whose patriotic beliefs might interfere with their capacity for objectivity, sometimes feel that the contributions of their particular countries have been slighted by the author and the same can happen in the field of the history of technology.

However, a work of the size and scope as that under consideration has as its goal to give a comprehensive picture, one deformed as little as possible by the particular preferences of the individual contributors. The greatest labors of the editors must certainly have been devoted to securing this result—and we must accordingly give them credit for its accomplishment.

TEXTILES AND TEXTILE MACHINERY

GRACE L. ROGERS*

The main object set forth by the editors of *A History of Technology* was to provide students of technology and applied science with some humane and historical background for their studies. For the subjects of Textiles and Textile Machinery the object was successfully fulfilled. There are many excellent contributions that make these volumes

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outstanding in the subject field of textiles; these, together with a few items requiring technical clarification and the mention of one or two omissions, will be covered in this critique.

Terminology in the field of textiles has not been standardized. The word "textile" itself, which is derived from the Latin *textilis*, meaning woven wrought fabric, can be interpreted in both a narrow and broad sense. In the first volume (Ch. 16) textile is defined by Grace M. Crowfoot in its strictest meaning, a woven fabric. However, the word is now accepted to include not only the product of weaving but also all spinnable fibers or materials suitable for weaving and, in addition to woven fabrics, fabrics produced by knitting and felting and all laces. This broader interpretation was sometimes given in Latin also, and the form *textile* was used as a transitive verb for plaited, braided, woven, or constructed. The term textile is, then, in its broadest interpretation a very general one. The point I raise here is not meant to be an exercise in semantics. It is only suggested that a more inclusive definition would have informed the reader, at the outset, of the broad scope that the subject encompasses. The initial subject chapter in a work as all-inclusive as this one must necessarily serve not only as a begining but also as an introduction to the subsequent volumes.

Limiting the definition of textile to woven fabric was probably responsible for the omission of any discussion of felt. Only briefly mentioned in the note on the materials under wool, felt is widely accepted as having an early origin. Producing fabrics by felting, treating wool fibers with heat, moisture, and pressure to form a compact material, it believed to have followed the wearing of skins and to predate both weaving and spinning.

Miss Crowfoot's section on basketry and matting is excellent. The techniques described are easily understood and the examples cited are numerous and well documented. The diagrams aid considerably in understanding the technical description and the photographs of the documented items add considerably to the general interest. Since no limiting definition of weaving was previously offered, I found it slightly disturbing to learn that matting formed by interlacing two sets of reeds or other materials at right angles was considered only "akin to weaving." In this work weaving apparently is limited to the production of a fabric on a loom. Such limited definitions can be confusing to the layman, if not clearly set forth, especially in the case of a term such as weaving already common to the reader's vocabulary.

In Miss Crowfoot's discussion of spinning the four basic natural fibers, wool, cotton, flax, and silk, are mentioned as represented in early archaeological textile remains. No further mention is provided as to the preparation of silk for weaving. Omitting the initial tedious operation, that of unreeling the silk cocoons or removing the seeds from cotton, silk requires less preparation before spinning than wool or

cotton. Silk is in reality already spun by the silkworm and only requires the twisting together of several strands for strength.

The "supported-spindle" is omitted from the definitions of the various spindle-spinning methods. One end of the supported spindle rested on the ground or in a small container of water. This is certainly the method that was used to spin medium and fine cotton yarns, which could not support a suspended spindle. Only very coarse cotton yarns could be spun by the Grasped or Rolled on Thigh Methods, the other two types discussed.

The general definitions and explanations of the various types of looms are very good. The diagrams are simple and easy to follow. The classification of weaves, however, seems a little confused, or, rather, over complicated. I believe this is probably due to an attempt to classify the known existing fabrics into too many subdivisions and also to a difference in the use of certain terms. In the United States the plain weave, type I, single wefts over single warps, is generally known as simply the plain weave. The term "linen weave" is no longer used. This, I believe, is a step in the right direction as, technically, linen can and has been woven in many weaves. There are, in addition, two basic variations of the plain weave. The one is known as "rib" and can be a warp rib, when the warps predominate and completely cover the wefts, or the weft rib, when the wefts completely cover the warps. The latter is a better term than "tapestry weave." Although tapestry weaving does use a weft rib weave, additional factors are also necessary, and the two are not interchangeable. It is especially confusing to see tapestry weave used to mean both a plain weave and later a pattern weave. The second plain weave variation, two or more wefts over two or more warps, is known in the United States as the "basket weave" (referred to as the canvas weave in this volume).

The term "pattern weaves" (Vol. I, p. 429) would have been more readily understood if it had been designated as "pattern fabrics in the plain weave." The explanations are all for the plain weave with patterns achieved by color variations, the tapestry weave presenting the one exception. Although basically a weft rib weave, the tapestry technique is one of carrying the weft thread only as far as it appears in the pattern and is considerably more intricate to execute than the preceding types. The explanation for producing a weft float fabric is rather limited. There are of course other methods of producing weft floats in addition to brocading, and these, though omitted in Volume I, are explained in later volumes.

The number of references and citations of specific examples of early fabrics are excellent. Furthermore, the fiber identification and thread count of individual fabrics add much to the technical interest. The photographs are excellent; it is regrettable that every textile mentioned could not have been illustrated.

The reader is given a true appreciation of the quality that the textile

arts had achieved by 500 B. C. It was both superfluous and unnecessary, I believe, to attempt to increase their stature further by expounding a popular theory of archaeologists that some early pattern weaves were so complicated that they would be difficult or even impossible to reproduce on a modern loom. By modern loom I presume is meant an automatic power loom. In adding power to the loom and in making the loom automatic, more and more strides were made to contrive methods more adaptable to the machine. There are many hand techniques that are impractical to attempt by an automatic machine. The goal is to reproduce the product, not to reproduce the action by which the product is achieved. Automatic modern looms use entirely different methods to weave pattern fabrics than those used with the simple hand looms of ancient Egypt or the Swiss Lake villages. A comparison is unreal and meaningless.

The subjects of spinning and weaving are covered very thoroughly in Volume II. The questions raised here are not ones of accuracy and clarity, which are for the most part unnecessary, but rather ones of omission of emphasis on the Eastern origin of the important textile implement improvements during this period. In the Epilogue of the second volume, "East and West in Retrospect," Dr. Singer gives full credit to the East for the many technological advances made there and introduced to the West. But R. Patterson's chapter on textiles (Ch. 6) makes no direct reference to the information in the Epilogue. Yet two of the most important textile improvements of the period, the spinning wheel and the treadle loom, are certainly of Eastern origin.

The description of the processing of wool fibers is very good. A minor error follows the description of hand cards where it states that the same type are used by hand-weavers today. Apparently Patterson meant hand-carders, for generally speaking hand-weavers today do not even spin their own yarn. And in the United States even hand spinners usually purchase their wool already carded. In the description of the method of using hand cards no mention is made of the angle of the wire teeth on the card clothing. It is essential to pull the cards across each other with the teeth angled in opposite directions to card the fibers and then to reverse the position in order to free or remove the fibers from the wire teeth.

After the description of bowing wool, reported to be an alternate method of processing, further details are omitted as to the manner in which the fleece is collected into a form suitable for spinning. Bowing wool, like carding, opens the fibres and frees them of dirt. But, unlike carding, bowing does not leave the fibers in roving form ready to be spun. Some limited form of carding must be performed after the bowing operation.

A minor omission but an important factor in the preservation of silk cocoons is the killing of the silk moth inside the cocoon, with the exception of the breed moths. Thus preserved the cocoons could be

kept for a considerable length of time before reeling. The section on silk reeling is excellent; the important link between the S-shaped flyer of the silk reel and the U-shaped flyer developed for the spinning wheel in the West is well presented. It is well-established that Leonardo da Vinci's sketch of a spinning device is not the earliest illustration that shows the use of the U-shaped flyer; credit previously given to him for the invention of the flyer has been correctly relegated to his probable origination of an even-winding device. The error of crediting the earliest known illustration, or the era of said illustration, as in itself establishing the date of any device was not uncommon in the past.

The subject of removing the seeds from cotton is treated rather lightly both in this and in later volumes. Patterson states that the cotton was removed from bales and beaten with sticks to remove the seeds and to free the fibers of dirt (Vol. II, p. 200). Such an operation would never have been used to remove the seeds, although it would have been effective for removing loose dirt. The problem of removing cotton seeds is not so much one of taking out the seeds but rather one of pulling the fibers away from the seed. Each individual cotton fiber adheres to the seed. No amount of beating would separate the two. Since cotton seeds contain much oil, such a beating would rupture the seeds and stain the fiber. It is most probable, even in the early centuries, that cotton was never shipped without the seeds having first been removed. The most primitive method of removing the seeds was by pulling the fibers free by hand, a slow and tedious process. This was the only known method in Pre-Columbian Peru. It was also the method used in India before the introduction of the roller gin. This simple implement, mentioned only briefly in Volume III, used pressured rollers to grasp the fibers and pull them away from the seed.

Figured fabrics are omitted in Volume II and covered in a detailed chapter on this subject in the next volume. This is the only practical way to handle such a highly specialized phase of the textile subject. However, since these volumes are used for reference and do state in their volume titles the specific period covered, it might have been well to have included a reference note to this effect at the end of chapter 16 of Volume II.

The development of the spinning and weaving techniques are covered both clearly and concisely for the period ca. 1500-1750 in Volume III, Chapter 7. The amount and excellence of the information offered in this one chapter by R. Patterson are noteworthy; the reader is given an informative view of the basic textile manufactures and a forecast of the new mechanical innovations that were just beginning to materialize. Progress in the mechanization of looms is well documented and interestingly illustrated, and the finishing operations are clearly defined and easy to understand, even by the novice.

The history of the development of the knitting technique together

with the well-executed illustrations make the "Note on Knitting and Knitted Fabrics" by James Norbury an extremely interesting addition to the chapter. Only one point of disagreement arises, that of the development of lace fabrics from the simple stocking stitch of the early knitter. Although lace-like fabrics can be knitted, true lace is considered to be only that produced by the needlepoint or bobbin methods, neither of which was derived from knitting.

In the chapter on Figured Fabrics (Vol. III, ch. 8), J. F. Flanagan presents the title term as one that can be used to denote any fabric ornamented by weaving, embroidery, painting, printing, or some other way. It is a great disappointment to find only those produced by weaving are included. Although it is most probable that all other methods of decorating fabrics were attempts to imitate the woven pattern, nevertheless I believe all the techniques should have been covered to some extent. The information on woven patterns is excellent and very thorough, but almost too much so for a volume of this type. This is especially true when the subjects of painted and printed fabrics, hand lace making, and embroidery, all so important in this period, are completely omitted.

It is quite understandable and certainly correct for the textile unit on the Industrial Revolution (Vol. IV, Ch. 10) to be dominated by the technological advances made in Britain. In this chapter, however, the authors' (Julia de L. Mann and W. English) criteria for the importance of an invention appears to be based on its use or acceptance in England, rather than on its importance to the world or to Western civilization. This must be the reason for both the complete omission of Eli Whitney's invention of the cotton gin and only passing mention of the invention of the ring spinning frame by John Thorp in 1828. More complete coverage of the ring frame is given in the last volume, relegating this important spinning invention to the post-1850 period when it came into common use in England. The only reference to Eli Whitney is in the section on Machine-Tools (Ch. 14) where K. R. Gilbert briefly identifies Whitney as the inventor of the saw-gin for cotton. Considering the economic importance of cotton ginning to the United States and indirectly to the whole world, based on the export figures for raw cotton, details concerning this invention should have been included in the textile chapter.

Except for the lack of treatment of the above mentioned inventions, chapter 10 is very thorough in Miss Mann's treatment of the important (English) textile inventions of the period. The various spinning devices of Hargreaves, Arkwright, and Crompton are explained in readily understood language. However, the illustrations are rather meager, and the two photographs negligible.

Mr. English's section on silk production and the spun silk industry, though representing a plateau, is interesting and well presented. Of special interest is the spun silk story; it, together with Pasteur's work

and the story of silk weighing, add scope to the period. The explanation of the principle of the Jacquard loom is good, but the diagram is rather weak. When one considers the important part played by the Jacquard loom from shortly after its innovation to modern times, it is rather underplayed. A photograph of an early Jacquard loom and illustrations of early Jacquard fabrics, especially ones such as the outstanding picture of the inventor woven on a Jacquard loom in 1839, would have added considerable interest to the story.

In the last volume the treatment of the textile subjects (Vol. V, Ch. 24) is once again quite good. Even though it becomes increasingly difficult to be thorough in a subject that grows in complexity with time and inventions, the authors, D. A. Farnie and F. A. Wells, achieve this task most satisfactorily: improvements in spinning and weaving are covered briefly but thoroughly; the sections on rug making, the sewing machine, and hosiery and lace are all extremely good and present a true picture of the technological advances in these related industries.

A few corrections should be noted. Although these do not change or alter the story as a whole, they are important. The first is in reference to the two American inventions by William Crompton, the fancy loom and the broad fancy loom. William Crompton did invent the fancy power loom, which he patented in 1837. The broad fancy loom was the invention of his son, George Crompton, and was patented in 1858. George Crompton also patented many other loom improvements in subsequent years.

In the section on the sewing machine several minor corrections are in order. The opening statement needs to be revised or qualified. Mr. Farnie states that the sewing machine did not attempt a mechanical imitation of hand sewing. This is untrue. For over fifty years many men attempted to do just that, mechanically reproduce the actions of hand sewing. These attempts were for the most part unsuccessful, but many mechanical devices for stitching were invented and patented. It would be more correct to say that the *successful* sewing machine did not attempt to imitate the hand stitches or the manner in which they were formed.

The illustration of the Howe sewing machine (p. 588) is of his 1845 pre-patent model, not of his 1846 patent model. Furthermore, the caption of this illustration states that the machine combined the eye-pointed needle and the underthread shuttle; in reality there is no underthread on this Howe machine, as the fabric was held in a vertical position, and the shuttle, in imitation of the loom shuttle, passed through a loop formed in the needle thread. It seems contradictory to state on page 588 that Howe patented a practical sewing machine in 1846, and on page 589 that Singer developed the first practical domestic sewing machine in 1851. Neither machine was completely practical in itself. The practical sewing machine, more than almost any other

invention, was dependent upon the work of several men. The Singer machines were no more or less practical than the Wheeler & Wilson machines(made under the Wilson patents) of the same period. The effectiveness of the Wilson four-motion-feed was much more important as a single feature than the straight needle of the Singer machine. It is a gross exaggeration to state that the 1851 Singer machine possessed every main feature. Nor is it correct that the Singer Company became the world's greatest producer of sewing machines in the 1860's; the Wheeler & Wilson Company, Singer's greatest competitor until the latter bought them out in 1907, still led in sewing machine production until the 1870's. Singer was responsible for the use of the treadle and the straight needle moving vertically; Wilson and others used a slightly curved needle in a vertical movement, not in the awkward horizontal movement of the Howe machine. The stationary rotary bobbin of Wilson is considered to be one of the most ingenious mechanical devices ever invented, and it completely dominated any other shuttle principle. Similarly, Wilson's simple, yet effective, four-motion-feed was immediately accepted and continues to answer that problem.

In my estimation these five volumes are excellent in their treatment of textiles and textile machinery, despite the errors and omissions which I have pointed out. One can only hope that a work equally as impressive can be published to record the many technological advances of the twentieth century.

MACHINERY

AUBREY F. BURSTALL*

There can be no doubt that for a long time to come the five volumes of *A History of Technology* are likely to rank as the first authoritative reference books in the pursuit of any enquiry about the history of machinery, for the scope of the work is very wide. The labor entailed in collecting and editing the material used must have been colossal, and nothing so comprehensive has been attempted before. The style for the most part is a clear concise English, unadorned with superfluous technicalities, and as such can be enjoyed by the ordinary modern reader with a taste for science and technology. The books are rendered even more valuable both for this purpose and as works of reference by the uniform excellence of the diagrams and illustrations which are

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of inestimable worth, being provided in most cases with sources and dates. Furthermore, the lists and indexes of figures, names, places, and subjects in these volumes add greatly to their usefulness as works of reference.

Since new machinery has been developed at an ever increasing rate in more recent times, it would be expected that the mechanical engineer should find more to interest him in the last volume than in the first. Surprisingly this is not so; for example, the sections in the first volume that deal with the origins of tools and machinery, and particularly that on the development of rotary motion before 600 B. C., are as readable and interesting as anything that is described as having happened during the last century. One is forced to the conclusion that the archaeologists who were the contributors to the first two volumes were much more skilled as writers and more resourceful in interpreting the artifacts of the past than the engineers or technologists who wrote about the developments nearer our own time.

The choice of period covered by each volume is not always satisfactory. Different authors in the same volume have dealt with varying periods of time, and there is some overlapping from one volume to the next, e. g., in the chapters on machine tools in Volume IV and V there is even the same illustration of a turret lathe. Because this is a history of technology, the history of the development of machinery is incidental to its main purpose and can only be inferred from what is written in some of the chapters. There is no consecutive sequence of events recorded from which the way that machinery has "evolved" can be directly evaluated as A. P. Usher has done in *Technology and Culture* (Vol. I, No. 2 [Spring 1960], pp. 109-127), though some of the sections contain useful material. For instance, the chapter on the origins of rotary motion in Volume I is excellent; the author brings out the contributions of the potter's wheel, the drill, and the wheel and axle, but the story is not continued in the later volumes so that the reader has to hunt around for the origins of the lathe and the means used for driving it. The more recent examples of rotary motion applied to vehicles are not at all well explained, for the problem of the friction between the driving wheels of the early locomotives and the rail gets scant attention, and the Ackerman steering gear for road vehicles is not even mentioned. To discover Reynold's theory of lubrication in Volume V we have to look in the chapter on Hydraulic Machinery, incidentally one of the best chapters on machinery in that volume.

A surprising mistake concerning rotary motion appears in figure 504 (Volume II) which depicts the hub of a wheel from the Dejbjerg wagon, dated first century B. C., with the statement that the grooves in the hub were for bearing rollers. The author makes the incredible assertion that the grooves were for rods of wood which turned between hub and axle to form a roller bearing. He might have known that the hubs and journals of roller bearings are not grooved, for if they

were, the rollers could not roll round between them. It is generally accepted that Leonardo da Vinci was the first to suggest roller bearings, though they did not come into general use until suitable hardened steel was available in the nineteenth century.

An important point in the history of rotary motion concerns the origins of the hand crank and of the crank and connecting rod. It seems to the reviewer that the first hand cranks in general use were the handles fixed to the upper stones of rotary querns in the Greek and Roman periods, so that the well known illustration from the Utrecht Psalter (Fig. 593, Vol. II) of a man sharpening a sword on a grindstone in the ninth century is not directly concerned, being much later than the earliest forms of the simple crank. The origins of the combined crank and connecting rod during the Middle Ages are more specifically and satisfactorily explained by Bertrand Gille, the author of Chapter 18, Vol. II, where there are some interesting diagrams of ancient cranes. It is a pity that in the later volumes this was not followed up with some chapters on the development of handling machinery. One of the most important uses of power in labor saving has been its application to lifting and handling machinery, but the way in which this has developed has yet to be recorded.

The development of machinery was closely associated with the development of prime movers, that is, machines for producing power. There is a chapter on this in Volume II, a chapter on windmills in Volume III, three chapters in Volume IV entitled "Power," "The Steam Engine," and "Water Mills," respectively, and five chapters in the last volume entitled "The Stationary Steam Engine," "The Marine Steam Engine," "Internal Combustion Engines," "Railway Engineering," and "Hydraulic Engineering." This choice of chapters by different authors is from the point of view of the mechanical engineer an unfortunate one. In Volume II the origins of the water mill and the windmill are well described, but the chapter on windmills in Volume III is less satisfying. It is largely descriptive of the construction and appearance of different types of windmill, with little mechanical detail of the essential parts, and output, speed, and load figures are seldom given. Since water wheels were the most important and powerful prime movers during most of this period (1500-1750), surely a chapter might have been devoted to them in that volume. The apparent omission has been dealt with by devoting a chapter in Volume IV to water mills for the whole period (1500-1850), which means that Volume III by itself is not a complete record of the progress of technology during its period; so readers must have access to all the volumes. The most important illustrations of water mills are to be found in the chapter on power which deals with windmills and steam engines as well, and here it is noted that the best chapter in Volume IV is the one on the early history of the steam engine by the late H. W. Dickinson; it is a model of conciseness, clarity, and consecutiveness,

and every one of the illustrations is first class. If other aspects of machinery development had been as well covered, these volumes would have been of greater value to mechanical engineers.

In Volume V the outstanding chapter is No. 22 on hydraulic engineering. Here the evolution of the various types of water turbine and other hydraulic machines is well explained, and the chapter concludes with an excellent summary of the fundamental contributions of Osborne Reynolds to the whole understanding of fluid machinery. The most important prime mover of all, and even now the heat engine producing power in the largest quantities—the steam turbine—is dealt with very inadequately in Chapters 6 and 7, where its significance for the future both as a stationary engine and for marine propulsion might have been pointed out. Here too the choice of subject for the chapters has been unfortunate, for the development of the steam boiler—a most important accessory—has had to be considered three times—for stationary engines, marine engines, and locomotives. The chapter on internal combustion engines seems to have an undue bias in favor of the automobile engine, natural enough today but certainly not so at the time in question, and the large gas engines that were being built before 1900 for the steel industry for blowing blast furnaces are hardly mentioned. One result of the unfortunate choice of chapter titles in Volume V has been the complete omission of any mention of the hot air engine. Thousands of these machines were built for supplying small amounts of power in all parts of the world between 1850 and 1900, and they also represent a most interesting technical achievement.

Probably the most cogent criticism of these volumes is the disconnected patchwork quality of the whole, a feature that is inevitable when so many different writers contribute from so many different points of view. Perhaps it is not fair to blame the editors for having produced a work of reference that lacks the narrative quality of an historical work produced by a single author. It is, for example, not easy to detect the gradual move toward automation in industrial processes or what has been significant in that regard, though many essential steps towards this goal had already been taken before the beginning of the present century. It is true that the progressive development of clockwork is well described--though not so completely as in Usher's book of thirty years ago (*A History of Mechanical Invention*)—and that the MacFarlane Gray hunting gear for steering ships is explained. The importance of this apparatus (1866) was that it was the first mechanical device to incorporate a differential screw for the measurement of the error in a closed loop control system. Other important devices associated with the beginnings of automation that receive little attention in these volumes are the gyroscope, the slide rule, Pascal's calculating machines, Babbage's difference engine, and the planimeter (about 1830)—an instrument for integrating areas

on a plane surface by moving a pointer round the boundary of the area to be measured.

There is an excellent review of scientific instruments up to 1850 in Volume IV, but this is not continued in the last volume. Hence the origins of some of our important instruments, such as Bourdon's bent tube pressure gauge (about 1850), have been omitted, which in view of the great importance of this pressure gauge to the safety of boilers and pressure vessels seems unfortunate.

The course of technology has so often taken a new direction as the result of historic accidents and disasters that one feels that more frequent reference might well have been made to these and also to mistaken lines of development in such blunders as the "stangenkünst" (power transmission by reciprocating rods) so popular in Europe at one time (as at Marly), the "man engine" (a vertical form of stangenkünst) used to raise and lower men in deep mines in Cornwall and elsewhere, and Brunel's advocacy of the atmospheric railway.

The gradual evolution of safety measures in the use of machinery might well have been given a chapter to itself. For instance, some extraordinary ideas persisted for many years about the causes of boiler explosions, so that a discussion of these and of the gradual dawning of understanding about the nature of the corrosion of metals would have been of great interest.

There is also an absence of information regarding the machines used for the testing of materials of construction, whereby their physical properties can be elucidated. One would have expected to find, for instance, illustrations of Musschenbroek's tensile testing machine (1729), Fairbairn's lever machine (1830), and Wohler's fatigue testing machine (1835). These are but three examples of machines of historic importance in the long search and research to establish how materials behave in use. The story has been well told by Timoshenko in his *History of Strength of Materials*, but some of it might well have been re-told in *A History of Technology* because of its great importance to the designers of machines and structures. This is one of the fields where mathematical analysis first began to be of use to practical engineers, and a fuller explanation of what has happened over the years would help us to understand the difficulties and doubts under which machine designers labored. From this point of view, Dr. S. B. Hamilton, the author of the appropriate chapters in Volumes IV and V, has given an excellent summary as far as structures are concerned, but no one has written adequately of the data and criteria used by the designers of machines to estimate their strength, output, and efficiency.

In another domain of machine construction, namely, machine tools, full justice has hardly been done. There are informative chapters on their development in both Volume IV and Volume V, but there seems to be some unnecessary repetition in the latter of matters already discussed in Volume IV, and the author of the later volume dismisses

in a few lines the important American achievements of synthesizing silicon carbide and finding suitable binders so that artificial grinding wheels could be made satisfactorily. Though he states that these completely revolutionized grinding techniques he does not make it evident that this was one of the most important factors to which the success of America in building automobiles was due in the decade that followed. The story of how this happened, and how other American achievements in machine tool manufacture took place, is now being recorded in a series of monographs by Professor R. S. Woodbury.

Another shortcoming in Volume V is the very inadequate treatment given to the new technology of refrigeration that was born during the period covered therein. The section on this subject takes up five pages only of the chapter on the preservation of food, and it contains no explanation of how refrigeration works, or of the cycles of operation involved, or of its connection with fundamental scientific discoveries. While the names of Jacob Perkins, Gorrie, Carré, Harrison and Bell, and Coleman are mentioned, the name of Linde, the inventor of the high pressure ammonia process (1876), does not occur anywhere, nor is there any mention of the absorption process. Mechanical refrigeration is one of the most elegant examples of the application of the theoretical principles of thermodynamics to practical use, and for this reason alone it would have been worth recording. Notable are the application of the regenerator and high pressures in compression, and the cascade method of reaching very low temperatures which eventually led to the making of liquid oxygen in 1895. The reader might at least have been given a reference in the Bibliography to what had taken place, such as Ewing's textbook on *The Mechanical Production of Cold*, published in 1908.

There is so much space given to the British contribution to the history of technology that one cannot help wondering if sufficient has been said of the contributions of the European states, Russia, China, and the U. S. A. When one considers the advanced state of technology today in these countries it is difficult to believe that they were not more advanced by the year 1900 than appears from reading Volume V. There are of course a few exceptions to these generalizations which make it all the more surprising that they are so few. One is the treatment of the internal combustion engine and the automobile which originated in France and Germany with the work of such men as Lenoir, Otto, Beau de Rochas, Daimler, Benz, Maybach and Diesel. Neither Britain nor the United States can claim to have been the innovators in this sphere, though the techniques of production that have since been applied to the making of these machines in the United States is one of the most remarkable technological aspects of the age in which we live. One would think that the foundations for these developments must have been laid before 1900 and that the history of technology in the United States up to that time would have given

more indication of the revolution in the methods of assembling machinery that were to be introduced by Henry Ford by 1913.

Any reference work of the magnitude of this, written by different authors, is bound to contain some gaps and omissions, and to some extent your reviewer feels that when there is so much of value that has been so excellently done, it smacks of pedantry to point them out. Let me stress, therefore, the extent of our indebtedness to those who produced these volumes. Already in the short time that has elapsed since their publication they have become a standard work of reference not only for students of the history of technology but also for practically everyone who wants to know what used to be done in any craft or industrial process in previous times. The chapters on the medieval artisan, describing so vividly the place where he worked, the tools he used, and the products he made, gives the engineering student an overall picture of the ideas, habits, and life of those days, so that he is better able to appreciate the achievements of the medieval period. Equally, the chapters on textile machinery and hand tools for wood and metal working are valuable additions to engineering literature.

The chapters that will probably be used for the longest time to come are those concerned with the "fringe" technologies where there is little historical material that is readily available to the layman. Among these, the sections concerned with farm tools, building, furniture, ceramics and glass, printing, coinage, food production, and chemicals are all outstandingly good. These crafts and industries have used machinery of some sort to an increasing extent throughout the ages, and the engineering student or other reader seeking to find how such machinery was operated will most often discover the answers to his questions in these volumes, as the reviewer has recently proved with a group of students reading engineering history.

This appreciation of the monumental task of producing the *History of Technology* would be incomplete without a reference to the concluding chapters in the last four volumes. These epilogues, as they are sometimes called, go some way towards explaining sequences of events on a much broader front for the various technologies. Those entitled "East and West in Retrospect," "The Rise of the West," and "The Beginning of the Change from Craft Mystery to Science as a Basis for Technology" will remain for a long time in the memory of the interested reader.

ELECTRICAL ENGINEERING

THOMAS JAMES HIGGINS*

The development of electrical engineering is unfolded in three chapters of *A History of Technology*: "Telegraphy," by G. R. M. Garratt, Deputy Keeper, Department of Electrical Engineering and Communications, Science Museum, London (Vol. IV, Ch. 22); "The Generation of Electricity" (Vol. V, Ch. 9) and "The Development and Utilization of Electricity" (Vol. V, Ch. 10), both by C. Mackechnie Jarvis, Director of C. Mackechnie Jarvis and Partners. The three headings comprise technical domains whose scope, course, and detail of development are so great that the contents of the chapters must perforce be limited to a connected account of major highlights.

Thus, "Telegraphy" is opened with a sketch of Chappe's telegraph (the line-of-sight semophoric system which dominated telegraphic communication in France over much of the period between its introduction in 1793, and its supersedence, in 1852, by electromagnetic systems) and with brief remarks on other visual systems. Next, a concise outline of electrostatic telegraphs (dated as stemming from a 1753 letter by C. M. in the *Scots Magazine*) and electrochemical telegraphs (traced from Salva in 1804 to Bain in 1846), none of which achieved commercial value of consequence, is followed by a fuller account of the electromagnetic type. In rapid succession Garratt outlines the basic discoveries in electromagnetic phenomena; gives details of Schilling's primitive system founded on use of Schweigger's multiplier (galvanometer); sketches Cooke and Wheatstone's improved needle-type instruments; remarks on the founding of the first commercial British companies; notes Morse's major contributions (relaying, extending signaling distance; the dot-dash code, facilitating and speeding transmission); describes the Bretts' pioneering work on submarine cables between England and France, followed by cables over the North Irish, and Mediterranean Seas and other important shorter-span waters; and concludes with an account of the laying of the Atlantic cables—a successful spanning in 1858, with eventual engineering failure in about three months; and, after an interim because of the Civil War, the 1866 spanning, with subsequent continuous cable communication. Seven illustrations (reproductions of woodcuts of early instruments),

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a glossy plate of Samuel Morse's telegraph instruments, and five book references round out the chapter.

The "Generation of Electricity" comprises eight sections, whose contents and relative importance are perhaps best shown by citing the section headings and noting the approximate page allocation to each: I. Early Sources of Electrical Energy (two and a half pages); II. The First Mechanical Generators of Electricity (four pages, including an interesting account of the origin and subsequent evolution of the meaning of the term "dynamo-electric"); III. Dynamo-Electric Generators (six pages); IV. The Gramme Armature and Its Successors (four pages); V. The Alternator (three pages); VI. Electric Lighting (eight pages, comprising a well-detailed account of the trend from arc lights to high-vacuum bulbs); VII. Electric Power Stations (seven pages, with emphasis on the early London central stations); VIII. Batteries (two pages). A page of pertinent references–approximately equally divided between books and articles–and some 35 illustrations buttress the text.

The chapter on "Distribution and Utilization of Electricity" can be similarly delineated: I. The Arc Light (five and a half pages); II. The Incandescent Filament Light (five pages); III. Telegraphy (six pages); IV. Automatic Telegraphy (three-quarters of a page); V. Submarine Telegraphy (one and one-fourth pages); VI. The Telephone (one page); VII. Wireless Telegraphy (one page); VIII. Transmission and Distribution of Electric Power (two and one-half pages); IX. The Electric Motor (two and one-half pages)–the whole rounded-out by some 22 references and 19 illustrations.

Each of the three chapters comprises a concisely-written, well-integrated, logically-developed, interestingly-illustrated entity. But, as noted at the outset, the technical area comprehended within each is of such vastness that only a most circumscribed account is possible within the allocated space. What is *given* is pertinent, well-presented, and technically accurate. But what *is omitted* exceeds this manyfold. Thus, various phases of development, of equal or greater importance, are not discussed–for example, electrical measurement. The work of many contributors of exceptional capacity is either not mentioned–as that of Oliver Heaviside, perhaps the most illustrious name in late nineteenth century telegraphy and telephony (The references cited on p. 444 of Vol. V must be to a different Heaviside than Oliver, so cited in the "Index of Personal Names"; no doubt the correct reference should be to his brother, a very well-known operating telegraph engineer. Oliver was primarily a theorist); or is not specified to the degree its merits–as that of Lord Kelvin, who almost single-handedly engineered the electrical aspects of the successful 1866 Atlantic cable.

Attention as a whole is focused heavily (as is to be expected in view of the genesis of the volumes) on British accomplishments. Hence the American reader will find little account of the development of

"generation" in the U.S., as manifested, for example, in Edison's d-c Pearl Street Station, Stanley's work on the high-voltage a-c transformer, and Westinghouse's pioneering a-c central station and transmission installations—work coeval with, and at least of equal importance to, the described developments in England. Nuances of much interest are lacking; thus an illuminative paragraph on the evolution of the commonly used secondary-voltage distribution values is not paralleled by a possible similar account of the evolution of the commonly used a-c frequencies.

These omissions are not, however, cited *against* the text, but rather are advanced as evidence of what is not *in* it. They indicate that the volumes cannot be considered as all-inclusive, at least with respect to electrical technology. What is said can be read with interest and with confidence in its technical accuracy—but with the knowledge that it focuses chiefly on the high spots of British development. But for a truly exhaustive account—of a technical phase or a topic therein, or of the personal work of an exceptional engineer—the reader must turn to the hundreds of specialized books and thousands of pin-pointed articles published on the material dealt with in the some 75 pages of the *History* (and of these, only a few are cited in its references).

The interested reader will find a ready guide to the English language sources in this reviewer's two exhaustive bibliographies (T. J. Higgins, "A Classified Bibliography of Publications on the History and Development of Electrical Engineering and Electrophysics," *The Bulletin of Bibliography*, [No. 3-7, 1950-1952]; and T. H. Higgins, "A Biographical Bibliography of Electrical Engineers and Electrophysicists," to be published in a forthcoming issue of *Technology and Culture*). These comprise some 4000 books and papers classified under appropriate subheads (as determined by personal reading of all but a few of the items cited) and arranged chronologically and alphabetically under these subheads. With such at hand, the interested scholar can easily find a wealth of information to complement that given in the *History*. For example, these bibliographies contain more than 300 titles on land and submarine telegraphy, including autobiographical or biographical accounts of many of the more prominent telegraph engineers, as compared with the *five* cited at the end of the article on "Telegraphy."

AUTOMOTIVE AND AERONAUTICAL TECHNOLOGY

JOHN B. RAE*

Three chapters in Volume V of *A History of Technology* deal with what the preface refers to as the technological basis for one of the major developments which mark the arrival of the twentieth century: the beginning of modern transport on the road and in the air. The evolution of road transportation is recounted by D. C. Field, Research Historian of the Veteran Car Club of Great Britain, in chapter 8 ("Internal Combustion Engines") and chapter 18 ("Mechanical Road Vehicles"); the development of flight is related by Peter W. Brooks, Technical Assistant to the Chairman of British European Airways, in chapter 17 ("Aeronautics").

The period which this volume covers (1850-1900) was one of somewhat fumbling beginning; it was only after the turn of this century that the internal combustion engine established its ascendancy as the power plant for highway vehicles and was recognized as the only feasible motive power for aircraft. The authors are therefore in the awkward position of having to stop before their story gets really interesting—almost, indeed, before it makes very much sense.

Since all the essential features of the internal combustion engine had been worked out by 1900, this chapter is the most complete and informative of the three. The author has covered the development of the internal combustion engine from the experiments of Christian Huygens and Denis Papin with gunpowder in the seventeenth century to the work of Rudolf Diesel at the end of the nineteenth. He has, moreover, not only traced the development of basic principles through such figures as Lenoir, Beau de Rochas, and Otto, but has also gone in some detail into such matters as ignition and carburetting systems, so that it is possible to find out, for example, that electric ignition goes back to Lenoir's gas engine of 1859 but that it had to compete with other techniques as late as Lanchester's gasoline engine of 1895. There is also a useful discussion of the problems of mechanical balance in multi-cylinder engines.

A particularly illuminating point is that the new technology, as frequently happens, began by following the familiar pattern of the old. In other words, the designers of the early gas engines thought in terms of the slow-speed reciprocating steam engine; some even tried to make a gas engine double-acting. It took a quarter of a century of develop-

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ment before Gottlieb Daimler finally designed a motor which broke away from the steam-engine influence.

Since Daimler promptly applied his engine to a highway vehicle, the story of mechanical road vehicles logically comes next. Here Mr. Field properly begins with the bicycle, which is correctly defined as a machine and which was an important precursor of the automobile. The evolution of the bicycle from the "hobby-horse" of 1818 to Starley's "safety bicycle" of 1885 is given completely; since Starley, there has been no radical change in bicycle design. The relationship between the bicycle and the subsequent development of the automobile, however, does not appear clearly even in the specific technical areas of experimentation with such things as variable speed transmissions, differential axles, and steel tube framing.

When he comes to the motor vehicle, the author gives an admirably detailed and concise treatment of pioneering with electric and steam carriages, and with gasoline cars as far as the European phase of their development is concerned. From the point of view of an American reader, however, this chapter suffers from the parochialism which pervades much of the fifth volume. The evolution of mechanized highway vehicles in Great Britain is described thoroughly, although the retarding effect of the "Red Flag Law" of 1865 is virtually ignored, and the repeal of the law itself in 1896 is not mentioned at all, despite the fact that this event was the occasion for a major celebration on the part of British automobile enthusiasts. The French story is also treated in detail; it would be exceptionally difficult to neglect the French contribution to the automobile in the 1890's. Germany's share is represented by discussion of the work of Daimler and Benz, but the only Americans who are mentioned are the Stanley brothers and Henry Ford.

Admittedly American motor vehicle development prior to 1900 was well behind European, especially French, and the Stanleys can be accepted as the most important American designers and builders of steam automobiles, but why Ford? He was neither the first nor the most successful pioneer builder of a gasoline carriage in the United States. His great achievements were the Model T and the moving assembly line, both definitely after the point at which this chapter closes the account. It would seem more appropriate to include the Duryea brothers or Elwood Haynes, or perhaps Hiram Percy Maxim and the Pope Manufacturing Company, who built 500 electric and 40 gasoline vehicles by 1899. Or, if the significant American contribution is to be considered (as it should be) large-scale production of motor vehicles, surely Ransom E. Olds and the "merry Oldsmobile" deserve recognition.

So that this comment will not appear to be simply the substitution of one variety of parochialism for another, let me also suggest that credit for designing the first true automobile, as distinct from a "horse-

less carriage," ought to go to E. C. Levassor rather than F. W. Lanchester. This point is perfectly clear in the description of the Panhard-Levassor car of 1891 on p. 430; yet on the following page, Lanchester's car of 1895 is hailed as the first motor vehicle designed as such.

The chapter on aeronautics, being the first and only treatment of the subject in these volumes, has to survey the whole history of man's attempts to fly from Daedalus to the Wright brothers, and occasionally beyond. The author has therefore had the unenviable task of handling an amorphous assortment of topics, with only the eventual attainment of powered flight as a unifying factor. He manages his materials well; it is no small achievement to compress pre-twentieth century aeronautics into 21 pages without any major omission.

Essentially, modern aeronautics begin with the Montgolfier and Charlière balloons of the 1780's, since earlier experiments in flight were isolated affairs without lasting importance, and even the ideas of Leonardo da Vinci, ingenious as they were, contributed nothing to practical aviation. Once the beginning was made, ballooning had a remarkably rapid growth; moored balloons were used for military observation as early as 1794, and it is difficult to decide whether to pay tribute more to the incredible courage or the incredible luck of the two brave souls who crossed the English Channel by balloon in 1785.

Ballooning inevitably suggested the propelled airship. The insoluble problem until the end of the nineteenth century was the provision of a satisfactory power plant. The author is consequently able to refer only briefly to the achievements of men like Santos-Dumont and Count Zeppelin, but it is to be regretted that he does not explain what kind of engines their first models carried.

When he comes to the evolution of heavier-than-air craft, Mr. Brooks does especially well in evaluating the achievements of men like Sir George Cayley and Otto Lilienthal in working out the fundamentals of aerodynamics, although he acknowledges that successful flight was achieved by trial-and-error and the accumulation of experimental data rather than by the systematic application of aerodynamic theory. There is a very valuable listing of the ingredients of a successful airplane on pp. 410-411, giving the dates when each item originated and the names of the individuals responsible. Chronologically these items run from Cayley's concept of the fixed wing in 1799 to the successful flight at Kitty Hawk in 1903. The great achievement of the Wright brothers, according to the author, was to identify the essential ingredients and combine them into a light but strong structure.

Interestingly enough, while Mr. Brooks is anxious to give the Wrights full credit without overlooking the vital contributions of others, he omits two reasonably important elements in the Kitty Hawk triumph. One is the work of the Wright brothers in Dayton with a homemade wind tunnel, which revealed substantial errors in the aerodynamic

computations of their predecessors. The other is their mathematical calculations on the design of propellers. In addition, while it may perhaps be a minor point, somewhat more recognition might have been accorded to Langley. The failure of the Langley machine to fly was due to mishaps in the launching gear, and the engine designed for it by Charles Manly was a radial motor, considerably in advance of its time.

There is also in this chapter considerable information on the early experiments with helicopters and rockets as well as the blind alley—so far—of ornithopters, or flapping-wing machines.

In summary, it can be said that all three chapters contain invaluable reference material. They do, however, leave the reader with a feeling of incompleteness. Perhaps this result is unavoidable; the story has to stop somewhere, and for the volume as a whole, 1900 is as valid a cutoff point as any. There are also, no doubt, considerations of space to be allowed for. Yet, I must regret that the authors could not have had a free hand to take motor vehicles and aircraft somewhat more deeply into the twentieth century, at least far enough to get them beyond the experimental stage and firmly established in modern technology.

Technology: The Continental Approach

L'HISTOIRE GENERALE DES TECHNIQUES

MAURICE DAUMAS*

In the French language, there is no satisfactory general work on the history of technology, although much has been written about it—indeed, too much has been written on a subject about which, on the whole, there is still little known. Among the publications of the past ten years, there is the French translation of Mumford's *Technics and Civilization*, but this is not properly speaking so much a "history" as the development of a very personal concept of history. There is also Pierre Rousseau's work, whose mediocrity is truly baffling (cf. *Revue d'Histoire des Sciences*, XI, I, page 93); nevertheless this work is often cited as a reference and figures in the bibliographies which professors of history give to their students. These two examples show the vacuum which still exists in French literature on this subject.

Our purpose was to try to fill this vacuum when we planned, with the best-qualified contributors, our *Histoire Générale des Techniques* (*General History of Technology*) in several volumes.

When we first projected this undertaking, the Singer *History of Technology* was not yet known; later on we realized that our plan and purposes were quite different from those of the English authors. For a number of reasons, we had decided to produce a work which would bring together a goodly collection of information and which would serve as the foundation for the study of the history of technology. Our work is meant for professors of general history and for their students, for sociologists and economists who require the basic elements of the history of technology in order to complete their personal researches. It appeared to us that this type of work could be of most service to a rather large public consisting of academicians and scholars; at the same time it could also promote, at least in France, the development of studies in the history of technology.

Indeed, by making available to the above-described public such a work, adequately reenforced by reliable references, we hope that the

* Maurice Daumas, Curator of the Museum of the Conservatoire National des Arts & Metiers and head of the Musées Techniques, is Editor-in-Chief of the *Archives Internationales d'Histoire des Sciences*. He writes here of the multi-volumed French *General History of Technology*, which is being published in Paris under his editorship.

history of technology can occupy a higher rank in general education and be treated more fully. In addition, we hope to promote the background knowledge of those who are attracted by the history of technology. In such a vast field, those who want to do thorough research must specialize. But one must have a general knowledge of the entire field which includes one's chosen specialty before one can become an expert.

That is the kind of basic work which we have planned. Even after the publication of *A History of Technology* we think that ours will have a well-defined use. For the French public at least, it can also serve as good preparation for study of the English work, and perhaps the same for the reading public of those countries into whose languages it might be translated.

The knowledge which, in a manner of speaking, is presented in somewhat "raw" form in the monographic chapters of *A History of Technology* will be presented in more polished form in *L'Histoire General des Techniques*. Our collaborators are also working from the original sources, of course.

Since the publication of the English work has for the most part preceded the editing of our French volumes, we cannot help but judge our own work, consciously or unconsciously, in relation to *A History of Technology*. However, as I have said, the works differ in approach, and I believe that ours will be decidedly different in style and manner.

The conditions of French publishing and of the French book market do not allow us to envisage as ambitious an enterprise as *A History of Technology*. At first we thought that our work would consist of two volumes of 600 pages each. After several modifications of our plans, our sympathetic publishers understandingly allowed four volumes of 600 pages, and we are determined not to go beyond those limits.

Our first two volumes are devoted to a description of the technological levels of different civilizations, treated either chronologically or geographically. We use this approach until the epoch when the development of machinery led to the elaboration of modern industrial civilization and the beginning of the rapid evolution of the last three centuries.

Thus Volume I consists of studies on those civilizations whose technological level attained a certain stability which was broken only by the introduction of techniques born in Western Europe. After a section devoted to pre- and proto-history, there is a section on ancient Mediterranean civilizations, another on the technology of Eastern Asia, and one on the transitional civilizations of Islam and of Byzantium. Finally, there is a study of pre-Columbian American technology.

Volume II begins with an important survey of the evolution of technology during the Western Middle Ages; that is followed by a similar investigation of the epoch of the Renaissance (although that term has little significance in the history of technology, in spite of what is often

stated in treatises of general history). In the second half of Volume II there begins a different kind of investigation. Each of the great fields of technology is treated in chapters or homogeneous sections, and this approach is utilized almost exclusively until the end of the work. Chronologically these studies carry those areas successively through the four centuries of modern and contemporary times, that is, from the seventeenth to the twentieth centuries.

This material is so abundant that we have had to resolve several problems in order to adhere to our editorial plans. First, the relatively limited amount of pages at our disposal (1500 pages for this portion of the work) imposed a certain degree of brevity upon us. Then it was a question of determining the division of the subject matter between the two and a half volumes left at our disposal. We adopted a period for each volume; the breaking point between them was difficult to determine, and, naturally, we did not stop at any precise date. Volume II comes to an end toward the first quarter of the eighteenth century—at the time when the Newcomen engine had just been put into use and coke was beginning to be utilized in metallurgy. These developments were of great importance, but there was no notable transformation in many other fields of technology at that same time; for example, one could choose quite different chronological cut-off points for the fields of printing, metrology, chronometry, applied chemistry, etc. Thus there is no rigorous concordance of time limits for each chapter. But we will deal only with the traditional evolution of each discipline, leaving to Volume III the first steps of the accelerated transformation.

Volume III will cover the period from 1725 to about 1855. We will avoid, I hope, speaking of "the Industrial Revolution." That term has meaning when one makes use of the history of technology in order to study the history of economics or sociology, but not when one speaks solely of technology. Indeed, this revolution can be dated about 1725 or in the neighborhood of 1783; but one is equally able to date it in 1829, and from 1860 on one can find a great number of transformations which follow one another in more and more rapid sequence. In fact, from the beginning of the eighteenth century on, technology enters progressively into a period of rapid evolution and constant acceleration.

If we have chosen the decade 1850-1860 as the breaking point between Volumes III and IV, it is because that decade corresponds to a clear break in the speed by which invention influenced industrial techniques. With the abundance of steel, the invention of high-powered hydraulic turbines, the mastery of electricity, the appearance of industrial electrochemistry, etc., we enter into a period when invention can make use of more and more numerous means of realization. The classical mechanizations begin to open the way toward "automatism," that word being used in its largest sense. The first universal expositions

(London 1851, Paris 1855) made the people of the most industrialized nations aware of these facts.

The authors of *A History of Technology* did not include the last half century, our own times, within their volumes. It appears to us that a general work on the history of technology cannot ignore this century. We believe that such a work should attempt to give as broad a view as possible over the entire domain of technology. Moreover, the history of technology can have quite different meanings, depending upon whether one curtails it at an earlier period or if one carries it to our own times. It would take too long to develop this theme, so I can only sketch it briefly here, pointing out only one of the reasons which appears to us to justify our conception. The past century of technical progress (1860-1960) is so rich in development, and research within that period involves such a mass of documentation, that it is necessary to begin its study immediately, before it has receded too far into the past, lest one lose the opportunity of knowing it thoroughly while there is still the possibility. Like everything young, it ages very quickly, more quickly than those developments which immediately preceded it, and much more quickly than during the millennia of high antiquity.

To summarize, our work will consist of four volumes whose titles will be approximately as follows:

I. The Origins of Technological Civilization.
II. The First Steps Toward Machinery.
III. The Expansion of Machinery.
IV. Contemporary Technology.

The editing of the first volume has been completed, and it will undoubtedly be published toward the end of 1960. By then the editing of the second volume will have been finished, and it will be published during the course of 1961. The remaining two volumes will appear regularly in the next two years.

The volumes will of course be illustrated by numerous line-drawings accompanying the text and by large plates. They are published by the Presses Universitaires de France in a series of publications which already consists of the *Histoire Générale des Civilisations*, in seven volumes, edited by Maurice Crouzet, and the first three volumes of a *Histoire Générale des Sciences*, edited by René Taton.

STORIA DELLA TECNICA DAL MEDIOEVO AL RINASCIMENTO, BY UMBERTO FORTI

GIULIO LENZI*

Umberto Forti's *History of Technology from the Middle Ages to the Renaissance* (*Storia della Tecnica dal Medioevo al Rinascimento* [Florence: Sansoni, 1957], pp. 650, with 432 illustrations and 34 tables) is divided into fifteen chapters (in addition to an introduction and a conclusion), richly illustrated with subjects selected with discrimination and taste. Despite the limitations suggested in its title, the focus of the book is quite broad. Since the relationships with both anterior and posterior developments in the realm of technology are so profound and vital, excursions outside the book's stated limits are understandably frequent.

Mr. Forti has written also for the non-specialist, the reader not particularly prepared by previous studies, or the discipline of research, in the history of science. Therefore, throughout the book references to the influence of economic and social conditions on the development of technology in various countries (especially as regards Italy) are numerous. For example, the vicissitudes of the *Arte della Lana*, and the *Ciompi* riots, in Florence (Chapter V) are acutely discussed in the context of the more general development of a capitalistic class and of the first monopolies.

The entirety of Chapter VI is devoted to Leonardo and the engineers of the Italian school. The discussion is concerned with, among other matters, Giannello della Torre and his pumping works for the Alcazar, and that of the Dutchman Rannequin for Versailles.

Chapter VII, on the art of printing, examines the production of paper, of wood engraving and type, the legends surrounding Gutenberg, and so on.

The development of naval art occupies Chapter IX, and includes discussions of the "*controvento*" (a sailing ship relying on the lateen sail, which allowed it to tack), galleys, the "*uscieri*" (in effect, floating forts, built to load, carry, and unload horses, soldiers, siege machinery, munitions, etc.—an early model of the *LST*), the first naval artillery, and narratives of the great naval battles (Lepanto, *et al.*).

Chapter X discusses the development of nautical instruments (the

* Dr. Lenzi, a former assistant in the University of Pavia, is scientific collaborator of the Milan Museo Nazionale della Scienza e della Tecnica (National Museum of Science and Technology). His review of Forti's Italian history of technology has been translated by Dr. Douglas F. Dowd, Associate Professor of Economics, Cornell University.

Amalfitan compass, the log (for measuring a ship's speed), the astrolabe, quadrants, the bathymeter (for taking soundings), and so on.

Chapter XI, on the new architecture and modern statics, fully discusses Giordano da Nemore and his influence on Leonardo.

Chapter XII examines the origins of the new dynamics: Tartaglia and his studies on the constant action of gravity on the motion of a projectile; Giordano Bruno; Galileo; the impulse theory of Giovanni (il) Filopono and Buridano; Giovanni Benedetti. The entire chapter is predominantly of scientific and philosophic interest.

Chapter XIII, dealing with optics and the development of astronomy, shows the importance of the work of G. B. della Porta, and exhibits (on the part of the author) a certain reservation on the priority of Galileo in the invention of the famous telescope presented at Padua in 1609.

Chapter XIV, concerned with medicine as a pure science, is more of scientific than of technical interest.

Chapter XV is a thorough and engaging narration of the origins of the glass and majolica industry, of the early achievements of this ancient art, of the splendor of Venetian glass, mirrors, and the like, and of their diffusion in the various European countries.

A comparison of the work of Forti with the monumental *History of Technology*, by Singer and his collaborators, is almost impossible. The latter embraces the history of all technics in all times, and results from the collaboration of numerous eminent scholars highly qualified in many fields. Moreover, it is devoted almost entirely to the study of technology alone: historical, political, and social references are only hinted at (except in the last chapter of Volume V which, however, is concerned with the modern era). Consequently, the philosophical, scientific, and purely theoretical references, discussions, and narratives are greatly truncated. The Singer history thus lacks chapters corresponding to Forti's XI, XII, and XIV. Instead, the Singer work—with the greatest detail and documentation—provides a profound historical analysis of the development of diverse technologies, and it is this that gives the work its exceptional value and authority.

Hence, one is able to conclude that the two works, although they have numerous common aspects and frequently draw on the same sources, have a different character and different aims throughout. But both—each in its own way and within its respective limits—are commended to the consideration and admiration of scholars.

THE SOVIET HISTORY OF TECHNOLOGY

A. ZVORIKINE*

A comparison of the British five-volume *History of Technology*, edited by Charles Singer, with the two-volume history prepared for publication in the Soviet Union reveals both similarities and differences. The similarity lies in the fact that both present the development of technology from the very beginning, setting forth the important discoveries and inventions, and telling about their makers. Factual material is identical to a large degree, as are the names of inventors, scientists, and engineers. The technical characteristics of discoveries and inventions contain essentially the same things, though not in equal detail.

There are, however, many differences in the directions the British and Soviet studies have taken. The size is the major formal difference: the British issued five large volumes, while the Soviet historians prepared two volumes, equal in size to one of the British volumes. The British *History of Technology* embraces the period from the appearance of the first implements to the beginning of the twentieth century, whereas the Soviet book goes on till the 1960's. The British authors devote most attention to the early period of the history of technology, while their Soviet colleagues stress the later periods.

The main thing is not this formal difference, but the way in which technology and its history are regarded. Differences arising from this approach can be classified as follows:

A. Differences in understanding the essence of technology and its laws of development.

B. Differences in the period division of the history of technology.

C. Differences in presentation for individual periods.

We shall deal in brief with these differences.

A. *Differences in Understanding the Essence of Technology and Its Laws of Development*

The British *History*, in Gordon Childe's discussion of the "Individual, Society, and Technique" (Vol. I, ch. 2), says: "Technology should mean the study of those activities directed to the satisfaction of human needs which produce alterations in the material world. In

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the present work the meaning of the term is extended to include the results of those activities. Any technology in this sense, like human life itself, involves the regular and habitual co-operation of members of a human group, of a society."

Further, the driving forces of technical progress are examined. These driving forces are linked with the aspiration to satisfy natural requirements in food, shelter, warmth, clothing, etc., i. e., the things that enable the individual to keep alive and produce offspring. It is stressed that the concept of these requirements constantly changes: what used to be a luxury may become a prime necessity, etc.

Soviet authors take a somewhat different view of the essence of technology and its laws of development. This view is presented comprehensively in my article recently submitted to *Technology and Culture*: "The History of Technology as a Science and as a Branch of Learning." * In contrast to their British colleagues, Soviet scholars center their attention not on human activities, but on the implements of labor. When defining technology, we stress its natural-scientific and social aspects. In summing up, the history of technology is described as "a branch of learning dealing with the development of implements of labor within the system of social production. From the point of view of natural science, the history of technology should show how man, to an ever greater extent, masters the laws of nature through his implements of labor, achieving a more profound, all-round use and application of natural substances and energy. From the social point of view, the history of technology should reveal the social motive forces and the socio-economic prerequisites of technical progress, the influence exerted by technology on the development of society, and the part played by the inventors and engineers of various nations."

B. *Differences in the Period Division of the History of Technology*

The British authors make the following period division:

1. From the early stages to the ancient empires.
2. Mediterranean civilizations and the Middle Ages (700 B. C. to 1500 A. D.).
3. From the Renaissance to the Industrial Revolution (1500-1750).
4. The Industrial Revolution (1750-1850).
5. The second half of the nineteenth century (1850-1900).

The Soviet book adopts a somewhat different period division of the history of technology. A theoretical elaboration of this period division will be found in our article "Certain Problems in the Period Division of the History of Natural Science and Technology" published in the

* Editor's note: This article will appear in the next issue of *Technology and Culture*.

journal *Voprosy istorii yestestvoznaniya i tekhniki* (Problems in the History of Natural Science and Technology, No. 4 [1957], pp. 153-162). In our division, we proceed from the premise that historical epochs differ not in their produce, but in the labor implements employed.

After an introduction—"The Purpose, Subject-Matter, and Methods of the History of Technology"—the Soviet *History* singles out the following periods:

1. The appearance and development of instruments of labor under the primitive-communal mode of production; the spread of simple implements and the appearance of complex implements (up to 3000 B. C.).

2. The development and spread of complex implements of labor under the slavery mode of production; the spread of complex implements operated by manual labor (3000 B. C.-500 A. D.).

3. The development and spread of complex implements of labor operated with the help of natural forces under the feudal mode of production (500-1500).

4. The appearance of prerequisites for the emergence of machinery in the manufactory period (from 1500 to the late eighteenth ctntury).

5. The appearance and spread of machinery operated by steam in the period of the triumph and consolidation of capitalism in the advanced countries (from the late eighteenth century to the 1870's).

6. The development of electrically-operated machinery in the period of the beginning decline of capitalism (from the 1870's to World War I, 1914-1918).

7. The preparation and realization of the transition to automatic systems in the period of the general crisis of capitalism and the building of socialism (from World War I, 1914-1918, to the present time).

C. *Differences in Presenting the History of Technology at Different Stages*

The British authors, like their Soviet colleagues, do not present the history of the development of inventive thought, but the history of technical progress in society in its direct connection with the development of production. For every given period the history of technology is analyzed through the development of its separate branches. Volume IV of the British *History*, for example, dealing with the Industrial Revolution of 1750-1850, has the following sections: (1) early stage of production, with technology described at the beginning of the revolution; (2) the development of power engineering; (3) industrial production, with a description of the development of chemical technology, engineering in the textile industry, the manufacture of ceramics, and machine-building; (4) the story of civil engineering; (5) the story

of technology in transport; (6) the story of communications technology; and finally, completing the volume, (7) a description of the scientific foundations of technology at that period.

The Soviet authors present the history of technology for each period in a somewhat different way: an introduction revealing the social and economic prerequisites of technical progress is followed by a review of the development of technology in different branches of production, according both to its historical and to logical progress. The Soviet authors proceed from the belief that a logical presentation actually provides a historical approach devoid of chance events.

Within the limits of each branch, inventions and discoveries are examined which gained recognition and affected the development of production at the given stage. This is followed by a brief description of inventions and discoveries chronologically belonging to the period discussed, but which served as a basis for technical advance in the subsequent period.

By way of illustration, here is the structure of the section devoted to the Industrial Revolution. The section is entitled, "The appearance and spread of machinery operated by steam in the period of the triumph and consolidation of capitalism in the advanced countries (from the late eighteenth century to the 1870's)."

The section contains the following chapters:

1. Introduction.
2. The first machines in textile manufacturing. (The chapter deals also with the development of chemical engineering, which is closely linked with the textile industry.)
3. The creation of an all-purpose engine.
4. The creation of machinery in machine-building.
5. Technical progress in metallurgy.
6. Technical progress in mining.
7. Technical progress in agriculture.
8. Technical progress in transport.
9. Technical changes in communication.
10. Technical progress in war industry.
11. New means of lighting. Progress in printing. Photography.
12. Inventions and discoveries which formed the basis of technical advance in the subsequent period.
13. The state of natural science.
14. Conclusion. The principal results of technical progress in the period under review.

The choice of the branches of technology and the order in which they are discussed is not fortuitous. Regardless of the multiformity

in the Industrial Revolution in different countries, technical progress evinced a definite regularity during this period. Machinery first appeared in the textile industry. It required a new motive power, the steam engine. To produce the first machines and engines, there arose the need to produce machines by machinery. The growing demand for metal led to the technical re-equipment of the iron-and-steel and mining industries. The growth of industry and urbanization confronted agriculture with new tasks. The Industrial Revolution culminated in changes in transport and communication.

Of course, this is a bare outline, but it reveals, through the tremendous variety of facts and phenomena, the *regular*, not fortuitous, pattern in the development of technology from the end of the eighteenth century to the 1870's. Technical progress has specific features and regularities in other periods, too.

A substantiation of the structure of the history of technology for each given period will be found in our article mentioned above, and dealing with the period division of the history of natural science and technology.

Organizational Notes

The complete program of the Society's Annual Meeting, to be held in New York City, December 27-29, 1960, will be mailed to the members. However, Dr. Carl W. Condit, chairman of the Program Committee, would like to make known the plans for the program insofar as they are complete at the moment.

THIRD ANNUAL MEETING

Belmont Plaza Hotel—New York City
December 27-30, 1960

Tuesday, December 27

2:00 p. m.—Belmont Plaza Hotel, Baroque Room
Joint session with the History of Science Society

TOPIC: Fairly Recent Science and Technology

Chairman: Lynn White, jr. (University of California at Los Angeles)

"Abraham Gottlieb Werner's Ideas on Science and Education"
Alexander M. Ospovat (University of North Dakota)

"The Engineering Gap between Faraday's Discovery of Electro-Magnetic Induction and the Electric Dynamo"
Harold I. Sharlin (Polytechnic Institute of Brooklyn)

Wednesday, December 28

10:00 a. m.—Statler-Hilton Hotel
Joint session with the American Historical Association

TOPIC: Technology as Cause in History

Chairman: Stanley Pargellis (Newberry Library, Chicago)

"Technology—Neglected Clue to Historical Change"
Roger Burlingame (West Redding, Connecticut)

"History—Neglected Clue to Technological Change"
Lewis Mumford (University of Pennsylvania)

Commentator: H. Stuart Hughes (Harvard University)

2:00 p. m.—Belmont Plaza Hotel, Baroque Room
Joint session with Section L, American Association for the Advancement of Science

TOPIC: Nineteenth Century Technology

Chairman: Sidney Withington (New Haven, Conn.)

"New Evaluations in the History of the Petroleum Industry in the Nineteenth Century"
Arnold R. Daum (Northwestern University)

"The British Electrical Industry Lag, 1882-1888"
Thomas P. Hughes (Washington and Lee University)

Commentator: Bern Dibner (Burndy Library)

Thursday, December 29

9:00 a. m.—Executive Council Meeting
Belmont Plaza Hotel, Blue Room A

10:30 a. m.—Annual Business Meeting of the Society
Belmont Plaza Hotel, Blue Room A & B

12:00 noon—Lucheon and Presidential Address by
Dr. Lynn White, jr.
Belmont Plaza Hotel, Crystal Room A & B

2:00 p. m.—Belmont Plaza, Baroque Room
Joint session with Section L, American Association for the Advancement of Science

TOPIC: Automation

Chairman: Preston R. Bassett (Ridgefield, Connecticut)

Speakers: James R. Bright (Harvard University)
John Diebold (New York City)

Commentator: A. J. Jaffe (Columbia University)

HOUSING ARRANGEMENTS

The housing arrangements for the Society's annual meeting are being handled by the Housing Bureau of the American Association for the Advancement of Science, with which the Society is affiliated. The AAAS Housing Bureau has arranged with five mid-town hotels for special, low, flat rates and has reserved appropriately large blocks of rooms for this meeting. Thus everyone making room reservations for the meeting of our Society is assured substantial savings.

The Belmont-Plaza Hotel, 49th and Lexington, will be the Society

headquarters. Members who wish to stay at the Belmont-Plaza during the meeting should make it their *first* choice in filling out the Housing Coupon which appears on the last page of this issue. The list of hotels and the reservation coupon are for your convenience in making your hotel reservation in New York. Please do not send your application to the hotel nor to the Society for the History of Technology; send it to the AAAS Housing Bureau in New York and thereby avoid delay and confusion. The experienced Housing Bureau will make assignments promptly; a confirmation will be sent you in two weeks or less. If requested, the hotels will add a comfortable roll-away bed to any room, at $3.00 per night. Mail your application now to secure your first choice of desired accommodations. All requests for reservations must give a definite date of estimated hour of arrival, and also probable date of departure.

Flat Rates for Rooms with Bath *

Hotel	*Single*	*Double Bed*	*Twin Beds*	*Suites*
Belmont Plaza	$ 8.50	$14.00	$15.50	$30.00 and up
Commodore	8.50	14.00	15.50	21.00 to 52.50
Biltmore	8.50	14.00	15.50	45.00 and up
Roosevelt	8.50	14.00	15.50	39.00 to 43.00
Waldorf-Astoria	10.00	16.00	18.00	45.00 and up

* All rates are subject to a 5% New York City tax on hotel room occupancy.

HOUSING RESERVATION COUPON

HOUSING RESERVATION COUPON

AAAS Housing Bureau
90 East 42nd Street
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Date of Application .....

Please reserve the following accommodations for the 127th Meeting of the AAAS in New York, 26-31 December 1960:

TYPE OF ACCOMMODATION DESIRED

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Suite .....Desired Rate .....Maximum Rate .....
(Desired rate and maximum rate apply only to suites)

Number in party ..... Sharing this room will be: .....

(Attach list if this space is insufficient. The name and address of each person, including yourself, must be listed.)

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First Choice Hotel .....**Second Choice Hotel** .....**Third Choice Hotel** .....

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(These must be indicated—add approximate hour, A. M. or P. M.)

NAME .....
(Individual requesting reservation) (Please print or type)

ADDRESS .....
(Street) (City and Zone) (State)

Mail this now to the Housing Bureau. **Rooms will be assigned and confirmed in order of receipt of reservation.**

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